INDUSTRIAL RESEARCH

FEBRUARY-MARCH, 1961

machines and decisions
a special report *one dollar*

PROFITABLE APPLICATIONS FOR CREATIVE MANAGEMENT

THE COVER, *photograph of a model designed by the Upjohn Co. to imitate impression-recording functions of the human brain, illustrates recent research of the last decade in this area, much of which has contributed to development of machines with human-like decision-making abilities – subject of the special section in this issue.*

Upjohn's "brain," limited to seeing and hearing, flashes lights to trace the pattern of related thought processes. The model points up needs for further exploration, such as the many studies now being conducted on biological-computer designs, teaching machines, and automated management-control systems.

Rapidly advancing technology, of necessity, is transferring many decision-making functions from man to machine. How computers are filling the void created by specialized manpower shortages or inadequacies is described in the special section on "Machines and Decisions." Of particular significance are the areas of management and education where the impact of mechanization already is felt.

° ° °

With this issue also – to provide a unique service to readers – Industrial Research announces formation of an Editorial Advisory Board comprised of the nation's topmost scientific, engineering, and management authorities. The special talents of these men are being tapped in an advisory capacity to assure I•R readers of authentic and useful information of significance.

The Industrial Research Editorial Advisory Board is listed for the first time on the masthead, under this half-page.

VAC **46,000** copies of this issue printed. Circulation audited and verified by Verified Audit Circulation Corp.

Industrial Research is dedicated to reducing the time lag between invention and production. It seeks to do this by informing technical management, creative engineers, and research workers of new scientific developments and their profitable applications in all fields of industry.

INDUSTRIAL RESEARCH

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Editorial: Professional science writers, industrial executives, research workers, educators, artists, and photographers are invited to query the editor at address above, with ideas for articles or art. Do not send manuscripts without query. Answers to queries are prompt.

FEB-MAR 1961

INDUSTRIAL RESEARCH

IDEAS AND APPLICATIONS FOR R&D MEN, CREATIVE ENGINEERS, AND TECHNICAL DIRECTORS

the eleventh issue of I·R

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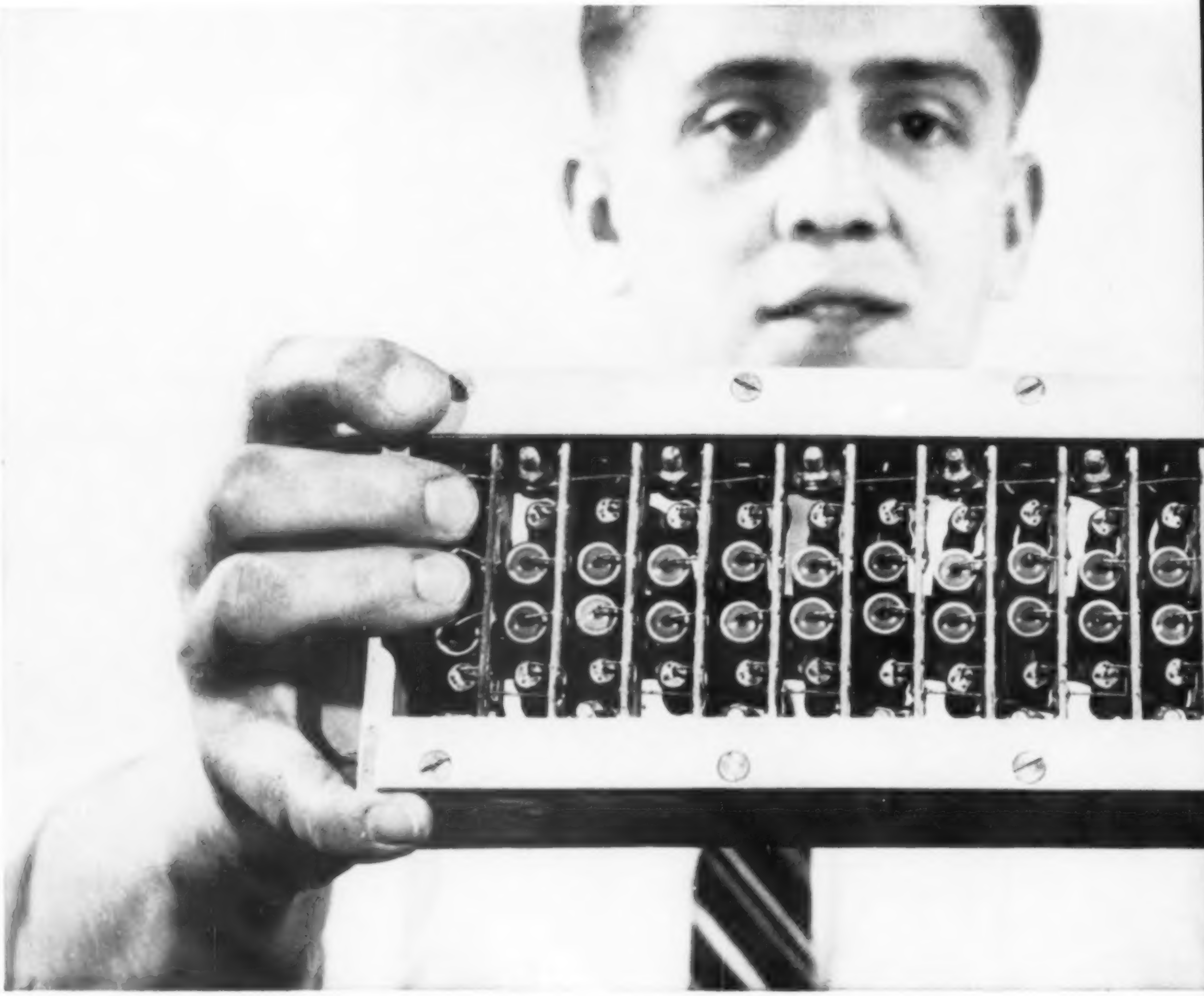
STATE-OF-THE-ART ARTICLES

SPECIAL SECTION: MACHINES AND DECISIONS

DEPARTMENTS



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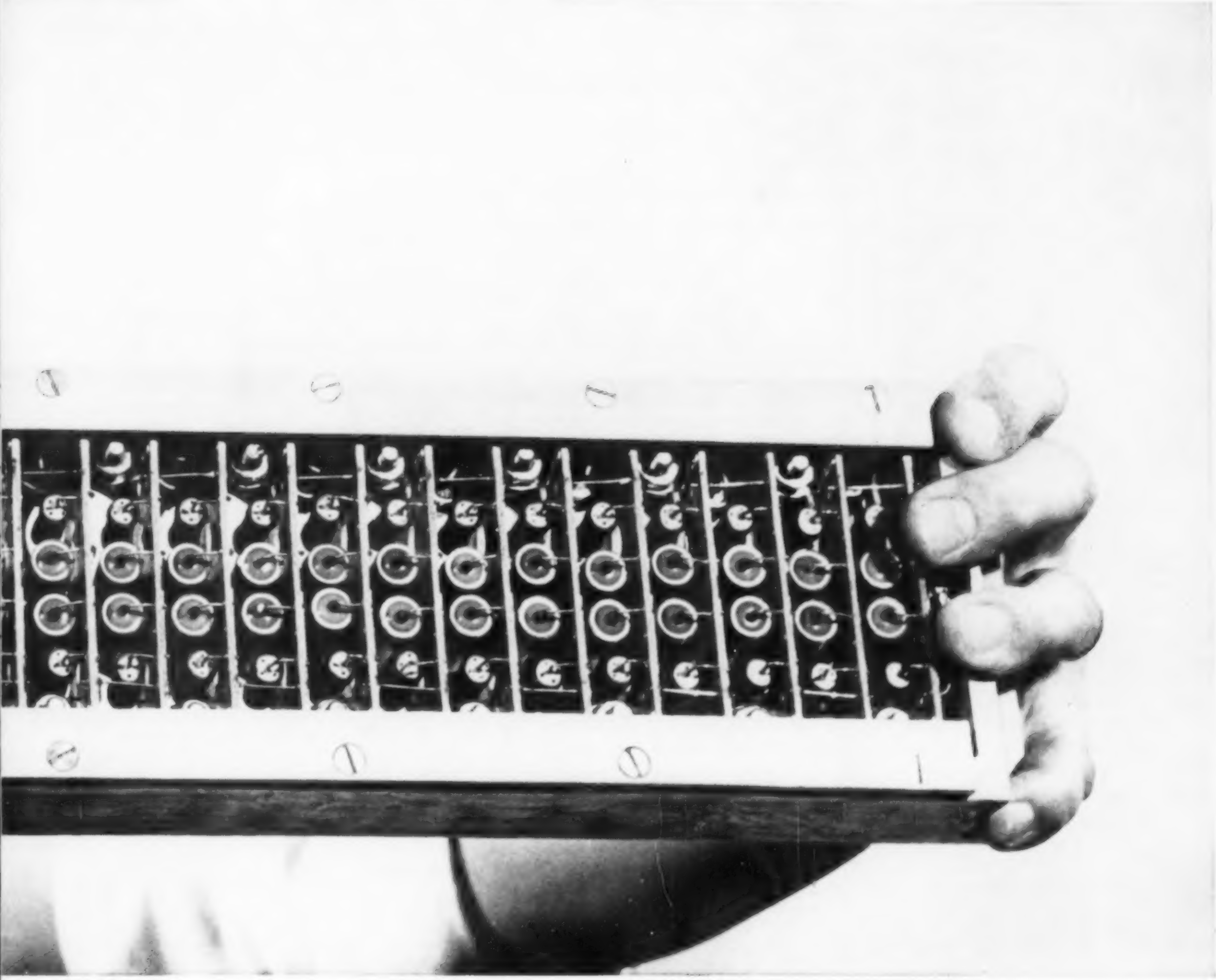
RELIABILITY PROVEN BY 17,000 KW IN FIELD APPLICATIONS

WESTINGHOUSE SILICON HIGH-VOLTAGE RECTIFIER STACKS



New Westinghouse Stacks top their own failure-free record! Number of stack-hours for units currently in use has nearly doubled in less than six months! Proof not only of outstanding reliability, but of an increasing industry-wide acceptance of Westinghouse Silicon High Voltage Stacks.

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Westinghouse Silicon Rectifier Stacks are available in a range of current ratings from 1.2 Amps to 18 Amps . . . from 9.6 K.V. to 35 K.V. For higher voltage requirements Stacks may be connected in series.

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MIL TYPE COMPONENTS

Unique Westinghouse modular inserts feature MIL Type shunting resistors, capacitors, and mounting boards. All components are 100% tested before and after assembly.

APPLICATIONS

- *Electrostatic precipitators*
- *Radio broadcasting transmitters*
- *Radar transmitters*
- *Ultrasonic transducers*
- *Radar pulse forming networks*

IR FEEDBACK *from readers*

Office copying machines

Sir:

Your article on office copying machines is an excellent review of the current state of some phases of the art, and should be most stimulating and informative to those who have not previously had an opportunity to examine detailed aspects of the field. It is easy to read, interesting, and accurate. Congratulations on a fine job.

The article certainly represents an excellent example of the fine results that can be obtained from the exhaustive type of research obviously performed by members of your writing staff prior to publication of material in your magazine.

I find your publication one of the most useful of the many which come across my desk.

Meyer L. Sugarman Jr.
Assistant Vice-President
New Product Research
American Photocopy Equipment Co.

Sir:

Our technical director, John Favorite, and others in our organization join me in commenting on your fair and comprehensive presentation of information in the article on office copying machines. The article was a good one, and one of the most comprehensive we have seen.

Sherman A. Lindell
Department of Communications
Minnesota Mining & Manufacturing Co.

Sir:

Under the "Thermo-Fax" process in your article on "Speedup in Office Copying," you state: "Originals must be in carbon or metallic inks."

Sheaffer's "Reproduction Permanent Jet Black Skrip" was developed for fountain pen and all-round writing requirements and it makes a record that reproduces very well by the Thermo-Fax process. The 3-M Co. has given this writing-fluid a rating of "six" on the scale ranging from one to eight, and considers it reproduces very well.

Carbon and metallic inks are not suitable for fountain-pen use.

Robert Casey
Research Laboratory
W. A. Sheaffer Pen Co.

(The article Mr. Casey refers to reads: "Originals must be of infrared absorptive inks, such as carbon-based or metallic inks." Fountain pen ink is not specifically mentioned. However, the paragraph goes on to explain that early difficulties in copying some printing inks and ballpoint-pen inks have been overcome with products now "on the market which give good results in thermographic copying.")

Sir:

The article on office copying machines is a very valuable contribution to knowledge of this dynamic rapidly changing field. It is changing so fast that it is hard to put down information one month which isn't at least partially incorrect the following month.

Joseph C. Wilson
President
Haloid Xerox Inc.

Computer applications

Sir:

The computer applications in the Industrial Research article (Vol. 2 No. 6) is well written and organized for easy reading.

Naturally, as general manager of Bendix Computer Division, Mr. Horrell would be biased toward the Bendix Computer line. It appears to be a free sales plug for Bendix Computers, since no other manufacturer is mentioned.

However, I think your readers will enjoy the interesting and fairly complete set of applications of computers contained in the article.

Walter W. Varner
Chief, Scientific Data Processing
Convair/Astronautics

Miniaturization

Sir:

The article "Miniaturization: Goal and Byproduct," by Theodore Berland, which appeared in your Aug.-Sept. issue is a splendid summation of the trend toward miniature components and circuitry.

Weldmatic Division of Unitek Corp. has made and is making a considerable contribution to reducing the size of computers and electronic modules. In fact, the photo on the MIT-Francis Associates digital-computer logic unit on page 20 is an all-welded module produced with weldmatic equipment.

My congratulations to Mr. Berland. His article was well written and is really a "hot" subject these days.

Don A. Drake
Weldmatic Division
Unitek Corp.

Editorial award

Sir:

May I extend my hearty congratulations on winning the Industrial Marketing Award so early in your career. I know that you are justifiably proud of this achievement since it provides a little public recognition for all the sweat and tears that you have poured into your publication since its birth.

May you have many successful years ahead with Industrial Research.

Harold Kaplan
Labline Inc.

Stimulus

Sir:

Your stimulating selection of articles from Industrial Research in book form, entitled "Stimulus," recently was passed along to me. It is really a very valuable book. I shall take it home and ultimately read it from cover to cover, and then use it as a reference.

I found your preface article most interesting and well-written. In itself, it provides some stimulating truths that should be self-evident but, as you imply, are not.

In your evaluation of the worth of scientific history we are in strong agreement. It reminded me of something the general manager of a large military electronics department once told me, rather regretfully: "Unfortunately," he said, "engineers do not write history." This same statement is true also, but to a lesser extent, of the more literate (generally speaking) scientist.

John J. Raffone
Technical Information
Bell Telephone Laboratories

Japanese computers

Sir:

The M-1 computer to which you refer in your article on computer progress in Japan was built at Nippon Telegram & Telephone Co. (a counterpart of AT&T in your country) for its own use. NT&T does not manufacture computers.

Incidentally, the name of the company is Fuji Communication Co. There are many independent Fuji companies in this country, for example, Fuji Bank, Fuji Steel, Fuji Film, etc. Fuji is as popular a company name as American . . . Co., or the like in your country.

Fujic, the first Japanese electronic computer, was built at Fuji Film Co., for its own use. This company is not marketing computers.

I also would like to point out that Kokusai Denshin Denwa Co. (Japan Overseas Telegram & Telephone Co.) is planning to build the first reactron computer for its own use. KDD does not manufacture computers.

Eiichi Goto
Department of Physics
University of Tokyo

(We've got to start brushing up on our Japanese!)

General feedback

Sir:

Congratulations on your magazine which has set such high standards from its very inception. I read each issue with great interest and reward in gaining specialized information in which I am interested. This certainly has been needed for a long tme.

Charles M. Smillie III
Michigan State University

Sir:

In connection with my responsibility for new-product planning for the manufacturing companies of the General Telephone System, it is necessary for me to keep abreast of all technical developments in any field which may be of interest to us. These include electronics, lighting, communications, chemistry, metallurgy, etc.

It is necessary, of course, for me to read many publications of both a business and a technical nature to try to cover the field. Most of these publications are merely scanned for specific items of interest, but I would like to report that Industrial Research is read from cover to cover, including all articles, editorial matter, and even advertisements. Keep up the good work.

Richard M. Klein
Manager of New Product Engineering
General Telephone & Electronics Laboratories Inc.

I·R wins citation

Pardon us for bragging, but we're proud of a new gold plaque gracing our walls.

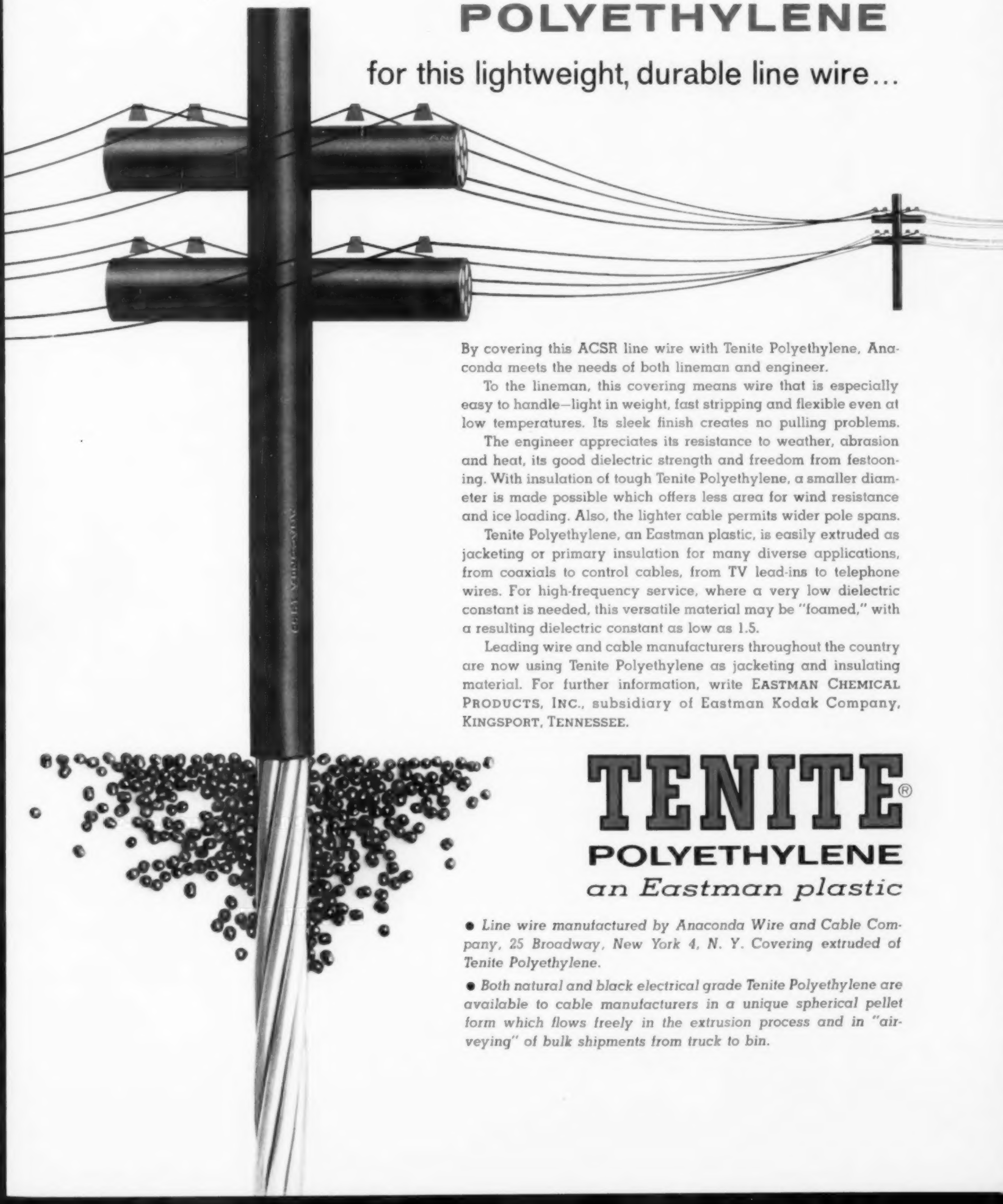
INDUSTRIAL RESEARCH *magazine has won one of three awards for editorial excellence in the best-design-appearance division of Industrial Marketing's 22nd annual Editorial Achievement Competition for Business Publications.*

Two Time Inc. magazines — House & Home and Architectural Forum — took the other two awards in the industrial publications category. House & Home won the first-place plaque; Architectural Forum and INDUSTRIAL RESEARCH *received certificates of merit.*

These magazines were selected from among 703 publications by advertising and industry leaders headed by Gustave Saelens, of American Cyanamid Co.

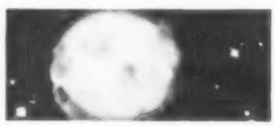
The April-May 1960 issue of I•R, which featured a photograph of a metal sculpture by Bertoia on the cover, was the issue submitted for judging.

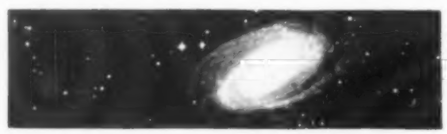
The award to the two-year-old INDUSTRIAL RESEARCH *magazine was accepted by Joseph F. Ryan, I•R marketing manager (see photo), on behalf of Neil P. Ruzic, editor & publisher, at the presentation Nov. 29 at the Waldorf-Astoria.* ■



WE'RE REACHING INTO SPACE

Bell Laboratories research with chilled ruby amplifiers speeds the day we may telephone via satellites





A strange combination of Nature's forces at Bell Laboratories foreshadows the day when world-wide phone calls may be relayed via man-made satellites orbiting the earth. It is a union of synthetic rubies and extreme cold, making it possible to amplify microwave signals from these satellites clearly.

Synthetic rubies possess an extraordinary property when deeply chilled and subjected to a magnetic field. They can be excited to store energy at the frequencies of microwave signals. As a signal passes through an excited ruby, it releases this energy and is thus amplified a thousandfold.

Bell Laboratories scientists chose a ruby amplifier because it's uniquely free of "noises" that interfere with radio signals. For example, it doesn't have the hot cathodes or hurtling electrons that generate noise in conventional amplifiers. It is so quiet that only the noise made by matter itself in heat vibrations remains. But at a temperature close to absolute zero, this also is silenced. Even very faint signals from satellites can be clearly amplified and studied for their possibilities.

Bell Laboratories scientists were first to discover that matter itself generates electrical noise. They also discovered that stars send radio waves, and thus helped found radio astronomy. It is particularly fitting that the same scientists, in their endless research on noise, should now battle this number-one enemy of telephony in the dramatic new field of communication via satellites. The ultimate goal, as always, is the improvement of your Bell System communications services.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

THE I·R 1961 FORECAST: $14-BILLION FOR RESEARCH

DAZZLING SPACE TRIUMPHS and record expenditures will highlight American research and development activities in 1961, according to most indications by government, industry, and research institutes.

Among the space conquests will be a manned orbital flight, a soft landing on the moon, a telephone switchboard space station, and the perfecting of weather and reconnaissance satellites.

Such scientific achievements will help push the nation's R&D spending close to the $14-billion mark—about 12% more than the estimated $12.5 billion spent in 1960.

The National Science Foundation some time ago predicted that research and development spending would climb only to $13-billion in 1961. However, Industrial Research believes that the NSF estimate will be surpassed by almost $1-billion because of several factors and findings:

1. Action by the new administration, which is critical of the defense program and committed to increasing the country's economic growth rate.

2. Continuing pressure of Russian scientific achievements, particularly in space exploration.

3. The findings of a recent INDUSTRIAL RESEARCH survey of government agencies, industrial laboratories, and research institutes, which indicates an R&D buildup even in the early months of 1961.

More than half of the $14-billion for research and development will be financed by the federal government, as has been the case throughout the 1950s. Yet, the bulk of the work—about three-quarters—will be performed by private industry.

Here's how the nation's estimated $14-billion research and development budget probably will be spent in 1961:

- R&D performed by industry, financed by government ......$5.2-billion.
- Government internal research and development .... 2.2-billion.
- Universities and other nonprofit institutes .... 1.6-billion.
- R&D financed by industry .... 5.0-billion.

The split between applied and

by **Victor J. Danilov,** *I·R editorial consultant, and the staff of Industrial Research*

HUGE BALL *in photo at top of page, of steel construction, will be used to test solid rocket fuels. It is being built at the Esso Research Center, Linden, N.J. At right, a two-piece lunar exploration suit is given a tryout by a staff member of Republic Aviation's life sciences laboratory, where the suit was developed as "working clothes" for an astronaut on the moon. For resting, the wearer can curl up inside the aluminum torso on a small built-in seat. Advanced models will offer complete indoor environment.*

EXPECT IN 1961:

- ★ Vaccines for measles and the common cold.
- ★ Greater understanding of the effects of radiation on life processes.
- ★ High-temperature fuel cells operating on natural gas.
- ★ Ultra-high-speed computer transistors and diodes.
- ★ New stereo rubber catalysts outside the Ziegler development.
- ★ Improvement in the cost and weight factors of solar cells.
- ★ Nuclear-powered merchant-cargo vessel.
- ★ Increased capacity and decreased cost of steel production.
- ★ Stronger, harder, and tougher plastics.
- ★ Strengthening of evidence that viruses are involved in the cause of cancer.
- ★ Discovery of the 103rd element.
- ★ Dehydration of foods through freeze-drying.
- ★ Elaborate private microwave systems.
- ★ An oral male contraceptive.
- ★ Stronger metal alloys.

DON'T EXPECT IN 1961:

- ★ Manned space platforms.
- ★ A satisfactory solution to the disposal of atomic wastes.
- ★ Economical conversion of saline water to drinking water.
- ★ A vaccine against cancer.
- ★ Manned landing on the moon.
- ★ Commercial jets traveling faster than the speed of sound.
- ★ Nuclear-powered planes or rockets.

basic research will be about the same as it has been in recent years, with 95% going into applied research and development and only 5% devoted to fundamental studies.

But there are signs that the ratio will be increased in favor of basic research in the coming years, as government and industrial leaders begin to recognize the imperativeness of uncovering fundamental knowledge on a systematic basis.

Industry's $10.2-billion

More than half of the $10.2-billion in research and development to be performed by private enterprise in 1961 will be concentrated in two industries — aircraft, missiles, and parts; and electrical and non-missile electronics.

This category will be followed by the non-electrical machinery and chemical industries—both of which receive substantially less government support for R&D.

The estimated R&D expenditures for industry—with approximate proportion of government financing—can be grouped as follows:

INDUSTRY (GOVERNMENT SHARE)	MILLIONS
Aircraft, missiles, parts (85%)	*$3,250*
Electrical, non-missile electronics (61%)	*2,000*
Machinery other than electrical (38%)	*875*
Chemicals and allied products (9%)	*725*
Professional and scientific instruments (30%)	*435*
Petroleum products (4%)	*325*
Fabricated metal products and ordnance (40%)	*275*
Telecommunications and broadcasting (55%)	*260*
Primary metals (gov't share unknown)	*175*
Food and kindred products (gov't share unknown)	*115*
Rubber products (gov't share unknown)	*100*
Stone, clay and glass products (1%)	*85*
Paper and allied products (gov't share unknown)	*80*
All other industries (23%)	*1,500*

A glance at the government-support percentages points out why the stepping up or cutting back of government R&D spending has such a drastic effect in some fields. Government funds finance more than half the R&D in such industries as aircraft, missiles, and parts (85%); electrical and non-missile electronics (61%); and telecommunications and broadcasting (55%).

On the other hand, federal expenditures constitute a relatively small proportion of industrial research and development in some fields, including stone, clay, and glass products (1%); petroleum products (4%); and chemicals and allied products (9%).

Budget boosts

Regardless of the source of the funds, it appears that virtually every industry will be devoting more attention to research during 1961.

Among the more spectacular budget increases reported in the I·R survey were 20% for Hoffman Electronics Semiconductor Division, 25% for Carrier Corp.'s research arm, and 15% or more for the Institute of Gas Technology.

One of literally thousands of problems being tackled in 1961 is tanker corrosion. If the problem is licked by the Esso Research & Engineering Co., Standard Oil and its affiliates could save $20-million a year.

Dow Chemical Co. estimates that 20 new products will result in 1961 from its R&D work, on the basis of 88 new products resulting from research introduced during the last five years. (These products accounted for more than 10% of Dow's total sales volume in 1960.)

Even more important is the fact that Dow's accelerated research effort has reduced the time required for a product to travel from laboratory to market. The journey took eight years in 1957, five years in 1959, and four in 1960.

A significant share of industrial research is for new products. Manufacturers estimate that 12% of their 1963 sales will be in new products developed since 1960.

The greatest increase in new products—27%—is expected by the transportation-equipment industry, mostly aircraft. Other industries forecasting high new-product sales proportions are electrical machinery (18%), non-electrical machinery (16%), metalworking (15%), and chemicals (14%).

The shape of 1961 research

In conducting its annual R&D survey, INDUSTRIAL RESEARCH asked industrial, governmental, and institutional leaders what effect they thought the change in administra-

1961 SPACE PREVIEW:

- ★ A manned orbital flight by the U.S. or U.S.S.R.
- ★ Unmanned soft landing on the moon.
- ★ Further space probes to planets and the sun.
- ★ Firing of two super rockets—the Centaur and the Saturn.
- ★ Launching of balloons and satellites with telescopes, making possible unobstructed views of Mars, Venus, and other planets.
- ★ A communications satellite.
- ★ Orbiting of an advanced Tiros "weather watcher."
- ★ Perfecting of photo and heat-detector reconnaissance satellites.

42-TON VACUUM CHAMBER *being installed at Republic Aviation's R&D center, can simulate conditions man will encounter at 150-mile altitudes. It is used to study space-equipment needs.*

tion and continued Russian scientific advances would have on the nation's research and development volume. Here are some of the more interesting comments.

Kent R. Van Horn, director of research for Alcoa, said neither Kennedy nor Khrushchev are likely to alter R&D expenditures to any extent.

A similar view was expressed by L. M. Currie, vice-president of the Babcock & Wilcox Atomic Energy Division: "I don't think the new administration will cause any major changes in atomic-energy programs, although there may be some acceleration in space efforts. Similarly, I think Russian technical achievements have been pretty well discounted and won't have any major effect on research spending in the U. S."

Robert Henderson, Climax Molybdenum vice-president, believes that R&D expenditures are "more a matter of timing and understanding" than a result of political changes and other outside influences.

However, others disagree. J. F. Downie Smith, president of Carrier Research & Development Co., summarized many of the replies when he said:

"I believe there will be a continued increase in expenditures for research and development, which obviously will be influenced by any successes the Russians may have, particularly in outer space."

R. P. Dinsmore, vice-president of Goodyear Tire & Rubber Co., likewise argues that the new administration, Russian achievements, and other external conditions are likely to stimulate research this year "because the universal answer to serious problems is the pinpointing of scientific investigation to their solution." However, he foresees more of a shift in emphasis than a major increase in research expenditures.

Current trends

Overall current trends in research are summarized by E. I. Green, executive vice-president of Bell Telephone Laboratories:

- The exponential rate of technological advance can continue, at least through the near future. Some slowing-down is already apparent in certain fields, but for technology as a whole the momentum still is building up. Saturation is not yet in sight.
- Technology is becoming vastly more complex. As a corollary to greater complexity, practically all technologies are fast becoming more interdisciplinary. Traditional boundaries between fields are collapsing.
- The cost of technological advance is going up at a disturbing rate because of the greater complexity, the highly competitive demand for technically trained personnel, and the general inflationary trend. Accompanying the increase in R&D cost is a growing requirement for capital investment in producing plant and equipment.
- An ever larger percentage of R&D effort is being conducted at government expense. Up to now, this has reflected another trend: increasing emphasis on national security. Government emphasis undoubtedly will continue, at least over the next few years.
- More and more emphasis is being directed toward human welfare, such as research on health and survival, plant and animal genetics and growth processes, food production and processing, and pharmaceuticals.

Specific developments that might be expected during 1961 follow:

Missiles and aircraft

This is the year that man will be hurled into space in an attempt to orbit the earth. Both the United States and the Soviet Union are poised for the historic shot. At the moment, it appears that the Russians hold an edge, but the American Mercury project may be ready early enough this spring to nose out the Soviets.

Present plans call for the project to be launched with a Mercury-Redstone rocket on 15-minute trial flight over the Atlantic. The missile will carry one of the seven astronauts about 160 miles high at speeds up to 4,000 mph.

The pioneering flight will be followed by several similar experiments, and then an attempt to orbit the earth with a manned satellite. The space capsule will circle the world three times at 17,000 mph in four-and-a-half hours, before re-entering the earth's atmosphere.

If successful, the United States will have recaptured the space exploration initiative from the Russians. If not, Americans may have a second chance with the proposed soft landing on the moon.

Wernher von Braun, director of the NASA's George C. Marshall Space Flight Center in Huntsville, Ala., is confident that the United States will achieve both the manned orbital flight and a soft lunar landing during 1961.

The trip to the moon will be an unmanned, one-way journey designed to test the feasibility of a manned landing and to transmit back to earth information about the moon's atmosphere and surface.

The moon landing will be attempted with the imaginative "Ranger" spacecraft. At launching, the Ranger's flanks are smooth, but once clear of the earth's atmosphere, it takes on a butterfly appearance. Two wing-shaped solar panels unfold and a parabolic radio antenna springs up. The panels seek out sunlight and power a miniature television camera during the last moments of the 240,000-mile flight. As the Ranger reaches the moon, a small capsule (referred to as "Tonto," of course) emerges from the craft, explores the nature of the lunar crust and telemeters the findings.

At least three balloon-borne telescopes and seven more satellites—all seeking to learn more about radiation in space, solar characteristics, and the nature of the atmosphere — also will be launched in 1961.

Among the more noteworthy satellites will be the S-51, an American Scout rocket with a British payload; the OSO (Orbiting Solar Observatory) that will keep its "eye" on the sun, and Ranger A-1 and A-2, two satellites that will be sent on million-mile trips into space.

The year also will see the launching of another Echo balloon satellite for passive bounce-a-signal-from-space experiments; the sending up of an advanced Tiros "weather watcher" during the fall hurricane season, and the first attempt by private industry to utilize satellites.

A T & T's satellite

American Telephone & Telegraph Co. plans to use NASA rockets on a cost-reimbursable basis to place a communications satellite in orbit. Under the proposed AT&T microwave satellite system, ground television or voice signals would be bounced off the satellite to almost any spot on earth. Upon striking the sphere, the signals would be flashed back to earth. Company officials estimate that the initial satellite will be able to handle 50 two-way telephone conversations at one time.

American missilemen will receive a lift where they need it the most—in magnitude of thrust—when the Centaur and Saturn are test-fired during mid-year.

The Centaur consists of an Atlas booster topped by a second stage burning liquid hydrogen. It will be able to lift 7,500 pounds into orbit or propel 2,000 pounds deep into space.

The Saturn, a 230-foot monster which will generate 1.5-million pounds of thrust on lift-off, is designed to send 25,000 pounds into orbit, or propel a two-man spaceship into orbit around the moon and back to earth.

On the military front, the United States will step up development of the Samos photo and Midas heat-detector reconnaissance satellites; make ready the Army Pershing and Air Force Minuteman missiles; and place the first Titan intercontinental ballistic missile into operational readiness.

The Samos satellite is said to be capable of taking photographs as good as those from the U-2 while it orbits at an altitude of 200 miles. The Midas satellite, less sensitive, uses heat detectors to pick up the exhaust gases of hostile ICBMs.

Will Dyna Soar?

In addition to serving as a strategic weapon, the 300,000-pound thrust Titan eventually will provide the booster for the Dyna-Soar, the highly publicized manned, hypersonic space glider.

The Martin Co. will build the booster and Boeing will be responsible for assembling and testing the unique craft, which the Air Force expects to be the forerunner of a rocket-launched passenger vehicle. When completed, Dyna-Soar will be capable of carrying passengers half way around the world in less than an hour.

Some space and aircraft projects will see results only after 1961. For example, there will be no manned space platforms or manned landings on the moon in 1961.

Plans for the commercial jet liner to travel at 2,000 mph also are bogged down. Some of the construction problems for such a craft are being solved in the Air Force B-70 program, but the project needs government money to supplement private investment.

Despite the 25 cents out of every research dollar going into missile, aircraft, and parts research and development, it takes time to do the possible and more time to achieve the improbable.

Nuclear energy

The question of additional funds also will receive a thorough airing in the nuclear research field during 1961 as a result of increasing pressure and a report by the President's Science Advisory Committee. The

RESEARCH FINANCING *breakdowns for 1961 are given in the bar and pie charts above. Photograph above shows the vacuum chamber used for testing an ion engine, developed for space travel by Goodrich-High Voltage Astronautics. At right, the Air Force's Titan is readied for flight testing at Cape Canaveral. Nose cone is a test model of a re-entry vehicle. The 98-foot-tall Titan, most advanced of U.S. intercontinental ballistic missiles, is expected to become operational this year. It develops 300,000-pounds thrust in its first-stage engine and 80,000-pounds thrust in its second-stage engine. The missile's airframe is produced by the Martin Co.'s Denver division, which also is responsible for assembly, testing, and weapons-system integration.*

committee has recommended that the level of government support for high-energy physics research be increased from $59-million to $135-million by 1963, and to $500-million by 1970.

The report, drafted by a special panel headed by Emanuel R. Piore, vice-president for research at IBM, says that the United States must continue to expand its research facilities and programs to maintain its position of world leadership in nuclear energy.

Whatever the outcome on the recommendation, nuclear research and development will continue to move ahead during 1961. Perhaps the most newsworthy development will be the completion and testing of the N.S. Savannah, the world's first nuclear passenger and cargo ship. One fuel loading will take it 300,000 miles, according to Babcock & Wilcox Co., one of the contractors.

The year will see the start-up of at least three more big atomic energy plants—Dresden, Yankee, and Indian Point.

There also is a possibility of a major breakthrough in the harnessing of new energy-conversion processes this year. Avco Corp. and 10 major private power companies are working together to put magnetohydrodynamics into the factory as a power source.

Several research centers plan to investigate spin-energy resonance techniques as tools in high-energy plasma research aimed at controlling fusion reactions.

Low-cost fusion

International Telephone & Telegraph may be nearing success in a low-cost fusion process. The process utilizes an electrostatic field in which clouds of electrons confine the hydrogen atoms in a small area. Most efforts to date have centered around the use of magnetic fields to confine the reaction.

Some of the most exciting nuclear experiments this year will be carried on by Argonne National Laboratory, which will complete construction of two new-type reactors—the "Juggernaut" and the "Janus"—early this year.

The Juggernaut is a versatile reactor with 25 times the power of its predecessors. It will be used to develop nuclear instruments and to conduct research in such areas as analytical chemistry and electronics. The Janus—named for the two-faced Roman god—will be used exclusively for biological research. The unusual reactor will play an important role in the study of the effects of different neutron doses in small animals.

A $17-million Fuels Technology Center also will be put into operation at Argonne in 1961. The new facility will be utilized in the investigation of nuclear-age metals and ceramics.

A fourth new Argonne installation that will have far-reaching implications is the Zero Gradient Proton Synchrotron, a powerful new atom smasher that should be completed in 1962. The synchrotron, housed in a doughnut-shaped structure 58 feet high and 210 feet in diameter, will accelerate particles to energies of 12.5-billion electron volts before smashing them into target atoms. The instrument will produce all 30 presently known or anticipated elemental particles in large enough quantities so that their properties can be determined with precision.

The atom's nucleus also will receive increasing attention from Brookhaven's new 33-billion electron-volt synchrophasitron, which was completed last year. The world's largest atom smasher is about the size and shape of a race course.

In addition to progress in smashing atoms, there is likely to be some advancement in the discovery of new elements. Glenn T. Seaborg, new AEC chairman, and others have hopes of increasing the number of identifiable elements from 102 to 103 this year, and eventually to 118 or more.

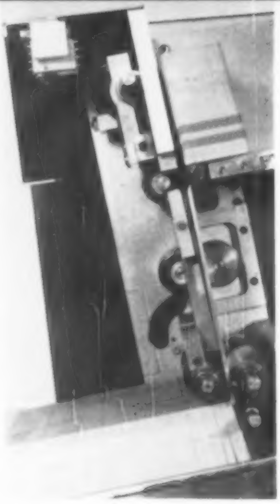
The outlook is not as promising, however, for solving the radioactive waste disposal problem, or for household use of irradiated foods, or nuclear-powered planes and rockets.

However, nuclear air power is under development at the Los Alamos Scientific Laboratory for the Atomic Energy Commission, and the project is expected to move from an experimental reactor to the engine hardware stage sometime during the coming year.

Life's chemicals

The art of re-creating life's chemicals will be intensified this year, following the 1960 achievements of synthesizing chlorophyll and discoveries concerning photosynthesis.

Robert B. Woodward, of Harvard University, already has synthesized bits of chlorophyll, as have German scientists. Another important contribution was made last year when a team of University of Pittsburgh scientists successfully developed the biological equal of ACTH, the cor-



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tisone-producing hormore that is invaluable to arthritis and rheumatic fever sufferers.

The year also is likely to see the development of successful measles and cold inoculations, an oral polio vaccine, and an oral male contraceptive.

Some 10,000 children will be inoculated this year against measles with experimental vaccines, based largely on the pioneering studies of Harvard's John W. Enders, a Nobel prize winner. If successful, one or more of the vaccines will be given the green light for large-scale production.

The National Institutes of Health is even more optimistic about a vaccine against upper respiratory diseases like the common cold and influenza, which affect as many as 20-million Americans each year. Two laboratory teams—one at the Laboratory of Infectious Diseases in Bethesda, Md., and another at the Merck Sharpe & Dohme facility in West Point, Pa.—reportedly have the inside track. Development of the live-virus vaccine has been slow because of the difficulties in mass-production.

Another development scheduled for 1961 is an oral male contraceptive, which temporarily arrests production of sperm cells. It now is being tested clinically at two universities.

The Rockefeller Institute and the University of California, on the other hand, are seeking to learn more about the causes of hereditary characteristics through the study of nucleic acids. Two of these acids—DNA and RNA—are believed to be the architects and modulators of heredity.

While there is little chance for development of a cancer vaccine this year, there is a good possibility that the relationship of viruses to the cause of cancer will be discovered.

Astronomy by radio

Major developments will be forthcoming in the fields of optical, radio, and solar astronomy during the year, spurred on by last year's dramatic feat of photographing galaxies in collision 6-billion light years away.

The National Radio Astronomy Observatory in West Virginia already is completed, and the world's largest radio telescope — a 1,000-foot-diameter dish—in Puerto Rico should be placed in operation this fall.

An underground solar telescope being constructed at the Kitt Peak National Observatory near Tucson will be completed in 1962. The telescope, which will reflect the image of the sun through a 380-foot-long shaft being bored in the top of the peak, will be used to study sunspots and solar flares.

Supermetals and higher temperatures

Work will continue this year on stronger, more resistant (especially heat-resistant) alloys for aerospace, nuclear reactor, and other uses. Several recent developments pave the way for further research:

One is the successful measurement of the melting point of technetium, found to be close to 4000 F. Another is a new process developed for producing single crystals of highly refractory metals and some of their compounds. Now the single crystals can be worked at lower temperatures than normally possible.

A new method for shaping and bonding metals together by powerful shock waves produced under water by an electrical discharge of some 20,000 volts will be explored.

Westinghouse has come up with a "blueprint" for the design of superweldable stainless steels that it expects to nearly eliminate the alloy's tendency to crack under the heat and stress of welding.

A new metallic compound with unique on-and-off magnetic characteristics will be put to work this year by du Pont. The new material—a brittle, gray manganese compound—becomes magnetic as the temperature rises above a point predetermined by its chemical composition, and then returns to nonmagnetic as the temperature drops.

Motivated by the 1960 emphasis on lowering steelmaking costs to compete with foreign labor and new foreign developments, Esso Research & Engineering Corp. this year will be working on a new method to produce steel more economically. Esso's concept calls for injecting hydrocarbons into the bottom of blast furnaces to increase capacity.

Mechanics: translators and bearings

Advances in mechanical engineering this year may be expected in a wide range of applications from improved hypersonic wind tunnels, for testing aircraft at speeds of Mach 15 and higher, to devices for cutting down air pollution from automobile exhaust (already offered on some 1961 cars).

Other developments to be expected include perfection of a 600,000-word "dictionary" to be used with a computer in the automatic translation of Russian technical literature at the rate of 360,000 words per hour.

Among efforts on electronic reading machines, one has been demonstrated that can be taught to identify correctly the letters of the alphabet after only 15 exposures; it can recognize letters in a typeface never "seen" before with 79% accuracy.

Frictionless bearings with high

NEW DEVELOPMENTS *from research include:*

1. *Uptime's Photo-Sensing Reader, which will read 3,000 punched cards a minute.*

2. *A Westinghouse sub-generator, one of two which make up the world's largest thermoelectric power plant.*

3. *An electrostatic generator, developed by Goodrich-High Voltage Astronautics to operate an ion space-propulsion system.*

4. *First nuclear-powered merchant ship, the 595-foot N. S. Savannah, a joint AEC-Maritime Administration project scheduled for completion this year.*

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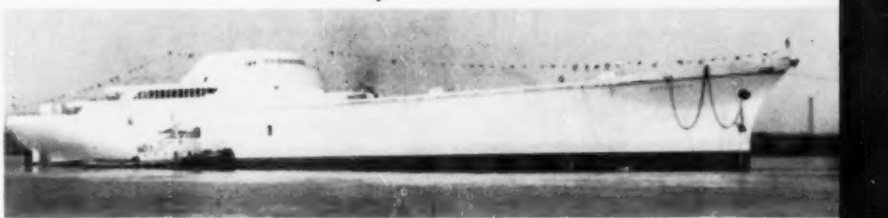

load-carrying characteristics and high-efficiency small motors are expected this year. Also, Ford's Aeronutronic Systems Inc. plans further tests on the Levicar, a frictionless vehicle attached to a rail by "levipads." A four-passenger experimental model is expected to provide design data for a later 40-passenger rapid-transit version.

A 10-hp diesel engine burning a fuel mixture of half oil and half coal dust has been built. An experimental gas-turbine-powered hydrofoil ship was developed that goes 50 mph on inland waters. And an experimental electric tractor powered by 1,008 fuel cells pulled a multiple-bottom plow through parched, packed earth. These advances point to the start of a 1961 revolution in land transportation as well as in farm machinery.

'Battle' for electronic dominance

One of the most significant techno-scientific "battles" to be fought this year will be in the area of microcircuitry. Albert G. Handschmacher, president of Lear Inc., feels there soon will be "haves" and "have-nots" in the electronics industry—those manufacturers which have in-plant microcircuit capabilities and those that do not. Firms that master the technique will be able to supply the latest type circuitry; those who do not have this capability will not be able to handle the business, except on a subcontract basis.

Microcircuitry—a means of making conventional electronic circuits smaller and more reliable—is fundamentally different from conventional electronics engineering and manufacturing. Because of their extremely small size, microcircuits must be fabricated initially as part of the electronic circuit in which they will be used.

Hoffman Electronics Corp. and other firms expect to develop new ultra-high-speed computer transistors and diodes and to improve the cost and weight factors of solar cells during 1961.

The new year also is certain to result in more advanced computers and improvements in peripheral equipment. For example, the Uptime Corp. photo-sensing technique will read punched cards at speeds from 400 to 3,000 cards per minute.

Developments last year also are likely to lead to a mushrooming of private microwave communication systems. RCA, for instance, came up with a device that permits utilization of microwave frequencies up to 20,000 megacycles, a level formerly not used for space communication systems.

And a new electronic transmission method, "thin-route-tropo," will undergo final tests; it requires an antenna only four feet wide and eight feet high, reducing transmission costs 60%.

Electroluminescence and thermoelectricity will be under continued study this year. The most powerful thermoelectric generator built to date will be tested further by Westinghouse Electric Corp. The generator, developed for the Naval Bureau of Ships, delivers five kilowatts of power by direct conversion of heat into electricity, without moving parts.

Chemicals: fuels and plastics

As research is directed toward turning heat directly into electricity, other projects are in the offing for converting chemical energy directly into electricity. A portable fuel-cell power plant already has been developed for mass production for the armed services. It has no moving parts, never needs recharging, but produces electricity to power radar systems directly from its fuel, the metal hydride.

The Institute of Gas Technology foresees development of high-temperature fuel cells operating on natural gas, and considerable progress in 1961 in delineating the most favorable processing conditions for producing synthetic high-Btu gas from coal and oil shale.

Amperex Electronic Corp. has produced a "plasma torch" that uses a radio-frequency field to generate temperatures approaching that of the sun, without consuming any fuel or electrodes. The torch has applications in such fields as the investigation of missile re-entry, spraying of high-melting-point metals and ceramics, petroleum cracking, and welding.

In plastics, polypropylene—a versatile material that retains its basic shape up to 290 F—will have more and more applications in packaging this year. Esso Research has devised a continuous process for producing polypropylene.

In the rubber field, Goodyear Tire & Rubber Co. expects to see improvements in production and quality of stereo rubber during the coming year. It is possible that new stereo catalysts will result from the work, and that stereo rubber will establish itself more firmly as the economic equal of natural rubber.

Whether any of the many projects reviewed here will bear fruit during 1961 of course is unpredictable, but a quick check of last year's *I·R Forecast for 1960* (Feb-Mar 1960 issue) will reveal that most of the laboratories' and manufacturers' hopes were realized, at least in part. It should be noted that literally thousands of research and development projects — possibly of equal significance to the ones presented—are underway, and that their omission here is due only to lack of space. Meanwhile, as always, research remains a gamble, but increasingly less so than the lack of research. ■

NON-STOP PRODUCTION OF LENS GLASS...

Where any metal but Platinum

PLATINUM DOES BETTER FOR LESS. In this hot end of the Bausch & Lomb continuous-flow furnace only platinum has the stamina to stand up long enough to return a profit. It is used as a lining material and in agitators and thermocouples.

It seemed preposterous at first. Line even part of a 5-ton capacity furnace with platinum? . . .

But the engineers at Bausch & Lomb had a case and proved it. The only *sure* way to contain glass at volcanic heat for month after month is in platinum.

The proof? Platinum melts at 3224°F (1770°C). Retains adequate strength at ophthalmic glass refining temperatures (2600° - 2700°F). Doesn't dissolve in the melt to discolor, or degrade quality. Doesn't erode or corrode in molten glass stream.

No other material provides the consistent purity essential to the economical mass-production of quality lenses.

The metal that masters molten glass may master a problem for you.

Where conditions involve high temperature and product purity, as in the production of lens glasses; or require peak catalytic efficiency, as in the refining of high octane gasoline; or a combination of severe corrosion and erosion must be met, as in the case of rayon production; or hard, highly con-

Platinum-lined five-ton furnace continuously fills molds with ophthalmic glass at Bausch & Lomb, makers of fine optical products. Furnace goes 18 months without shutdown. Glass must pass 23 quality tests.

would cost too much...

ductive surfaces, as in the production of printed electrical circuits; and many other products, the platinum metals have proved to be most economical.

Progress in research and development indicates a growing need for materials to cope with higher temperatures, higher pressures, more severe combinations of operating conditions . . . materials of proven ability to deliver long, trouble-free service life. To this end the unique potentials of the six platinum metals are being thoroughly explored on a continuing basis.

Platinum, palladium, ruthenium, iridium and rhodium *all* have unique properties, well worth your attention. Specialists are prepared to work closely with you in evaluating these metals for new commercial and scientific uses.

As a first step, write us for additional data on the unusual properties and successful applications of the six platinum metals and their alloys – indicating your field of interest or how we might be of assistance.

CAN THESE PROPERTIES OF THE PLATINUM METALS HELP YOU?

High Temperature Stability
Exceptional Chemical Inertness
Superior Wear Resistance
Peak Catalytic Activity
Low Vapor Pressure

The six platinum metals are:

PLATINUM · PALLADIUM · RHODIUM
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I R

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New products

☐ SILICON RECTIFIER STACKS that double the number of stack hours for units currently in use are available in a range of current ratings from 1.2 amps to 18 amps, for 9.6 K.V. to 35 K.V. For additional information, write to Dept. SC-1016, Westinghouse Electric Corp., Semiconductor Dept., Youngwood, Pa.

☐ A MAJOR CAUSE OF TRANSISTOR FAILURE can be eliminated by building a transistor inside its own shell. The new method, called "Planar Structure" is explained in a 12-page brochure available from Fairchild Semiconductor Corp., 545 Whisman Rd., Mountain View, Calif.

☐ SILICONE FLUIDS developed by Dow Corning make it possible to design more efficient mechano-fluid devices. They are resistant to oxidation, are non-gumming and non-sludging, and are serviceable at temperatures from −100 F to +400 F. Write for a descriptive brochure to Dept. 4414, Dow Corning Corp., Midland, Mich.

☐ HIGH-DENSITY RECORDING system, with each reel of one-inch tape holding as much data as 11 reels recorded by conventional systems, has been developed for highly reliable computer applications. The system permits data transfer rates of 360,000 alpha-numeric characters per second or more, at densities of 1,500 bits per inch on one-inch tape. Write to Potter Instrument Co. Inc., Sunnyside Blvd., Plainview, L.I., N.Y.

☐ NON-CONTACT-CAPACITANCE gaging is now practical and economically feasible with measuring instruments developed by The Decker Corp. Any variable that is converted into a change in capacitance can be measured, recorded or controlled by the instruments which incorporate ionized transducers. Write to The Decker Corp., Bala-Cynwyd, Pa.

☐ ULTRASONIC CLEANERS with feedback control provide maximum reliability and efficiency for cleaning operations. Send for a copy of ultrasonic cleaning booklet, Dept. IR-2, Powertron Ultrasonics Corp., Patterson Pl., Roosevelt Field, Garden City, L.I., N.Y.

☐ TEMPERATURE INDICATING PAINTS which change from one color to a different one when certain temperatures are reached, have been developed for use in hundreds of operations. Write for folder to Curtiss-Wright, Princeton Div., Princeton, N.J.

☐ DUAL-BEAM OSCILLOSCOPES permit the display of four different waveforms at once, and operate in conjunction with any combination of 16 "letter-series" plug-in units to provide signal-handling versatility and reliable performance. Write to Tektronix, P.O. Box 500, Beaverton, Ore.

☐ LIGHTWEIGHT LINE WIRE with jacketing or primary insulation of tough polyethylene that meets the needs of both linemen and engineers is available from Eastman Chemical Products Inc., Kingsport, Tenn.

☐ POWERFUL CARBON ARC is available for use as artificial simulator of solar energy in the development and testing of space vehicle components. Write to The Strong Electric Corp., 390 City Park Av., Toledo 1, Ohio.

Ideas

☐ PLATINUM METALS provide high temperature stability, exceptional chemical inertness, superior wear resistance, peak catalytic activity, and low vapor pressure characteristics for new commercial and scientific uses. Write for application data to Platinum Metals Div., The International Nickel Co. Inc., 67 Wall St., New York 5.

☐ AN ELECTRONIC COMPUTER ordinarily is a large expense. But Bendix Computer has information showing how at a low initial investment, without adding special personnel or facilities, you can start now to provide your firm with the money-saving speed and precision of electronic computation. For application and other information, write to Bendix Computer Div., Dept. Y-29, Los Angeles 45.

(continued on page 61)

RESEARCH

TRENDLETTER

Feb-Mar, 1961

Dear Sir:

New increases in the output of thermoelectric cells, breakthroughs in development of other unique power sources, and the introduction of products using these sources all indicate growing research emphasis in energy conversion. (This also will be the subject of a special edition of Industrial Research, to be published next Fall.)

Latest evidence is that thermoelectricity's figure-of-merit (an index of quality) has no technical limit, according to papers presented at the Symposium on Thermoelectric Energy Conversion in Dallas last month. Proceedings of the symposium, which was sponsored by the Navy and seven technical societies, will be published by Perganon Press, 122 E. 55th St., New York 22.

Most recent thermoelectric product on the market is a line of generators for commercial and industrial uses, produced by the Westinghouse Semiconductor Dept., Pittsburgh 30. The generators have no moving parts, can produce low-voltage, high-current d-c, and can operate unattended and trouble-free for long periods in remote locations. Westinghouse is offering four sizes--5, 10, 50, and 100 watts--and will produce other ratings on order.

Other thermoelectric devices now being sold "off-the-shelf" include mercury-vapor coolers (Minnesota Mining & Manufacturing), transistor coolers (Westinghouse), and elements and modules (General Thermoelectric and Melcor).

power

A fuel-cell power pack weighing only 45 pounds--replacing 1,000 pounds of batteries--soon will be delivered to the Marine Corps by General Electric's Aircraft Accessory Turbine Dept., Schenectady, N.Y. Models like it will not be available to industry for several years, however.

A gas turbine which will reduce engine weight from 5,000 to 600 pounds on earth-moving and construction equipment is being tested at U.S. Army R&D Laboratories, Ft. Belvoir, Va. The turbine, developed by General Motors to replace conventional Diesel tractor engines, requires heavier gearboxes, which somewhat offsets the weight reduction. Horsepower increases slightly--from 200 to 206.

communications

An experimental communications system employing ultraviolet radiation as a carrier frequency has been demonstrated by Westinghouse Electric Corp., Pittsburgh 30. Experiments to date indicate ranges of 15-million miles can be achieved. At lunar distances, ultraviolet radiation would be sufficient for the transmission of video information. As a carrier, ultraviolet should prove superior to infrared and radio waves because antenna gains of several million can be achieved and because ultraviolet systems are relatively free of celestial and thermal noise.

Military and commercial microwave communications systems may become a reality because of the development of new Varactor diodes by RCA, 30 Rockefeller Plaza, New York 20. The Varactors, smaller than buckshot, are so sensitive they will pick up and amplify microwave signals transmitted at frequencies close to those of infrared.

Microwave systems which may result from the diode advances will be superior to present communications systems because the microwaves will be virtually immune to enemy jamming, will extend communications into the higher radio bands, and will use small, low-cost, long-lived receivers.

computers

A memory cell made up of three cryotrons has been developed by IBM, 590 Madison Av., New York 22. The cell, which combines storage and elementary logic operation, may allow all memory storage points within a computer to be searched simultaneously--a time-saver over the present sequence-search process. The postage stamp-size memory unit formed from the three-cryotron cells is shown in photograph No. 1.

Latest development in computer language, "cobol" (common business oriented language), makes it easier than ever to talk to machines because it uses plain English. With cobol, computer programs in English for the first time have been interchanged successfully between data processing systems of different manufacturers--RCA, 30 Rockefeller Plaza, New York 20, and Remington Rand, 315 Park Av., New York 10.

Remington Rand claims as a major scientific breakthrough its practical thin magnetic-film memory, which permits computers to operate in billionths rather than millionths of a second.

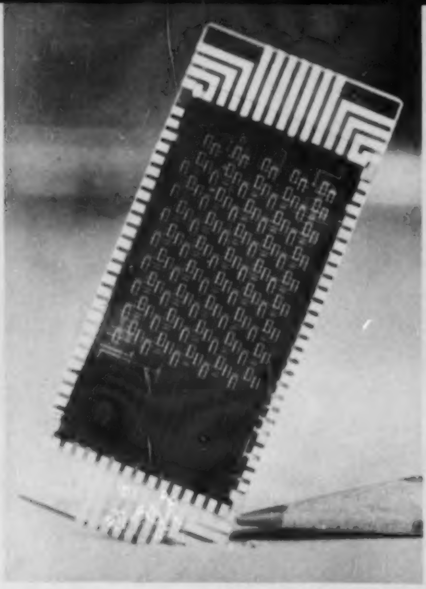
A closed-loop control system is being put into operation at a catalytic cracking unit for the first time by Gulf Oil Corp., Box 1166, Pittsburgh 30, at its Philadelphia refinery. A computer now will control the two major process variables--reactor temperature and recycle ratio. Automatic operation is expected to result in efficiencies within 5% of theoretical perfection.

Based upon previously established records, a reliability of better than 99.5% is predicted for the digital computer being used, the Thompson Ramo Wooldridge RW-300.

An analog simulator, equivalent to 50 analog computers, will be used in flood-control operations within the Kansas River basin. Being designed and built by the Civil Engineering Dept., University of California at Berkeley, the simulator will help engineers decide when to store or release water from reservoirs during flood threats.

aircraft

A three-dimensional air traffic control system, often suggested as the answer for preventing such disasters as the recent mid-air collision over New York City, actually has been developed and has been in successful operation for several months in Zurich, Switzerland. To produce the 3-D system, Contraves A.G. of Zurich combined its Fledermaus Radar System with the Iconorama (three-dimensional data processing and display system) of Fenske, Fedrich & Miller Inc., Los Angeles.



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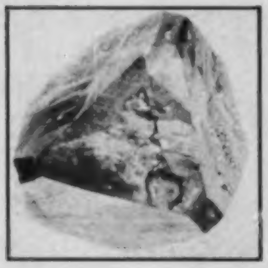

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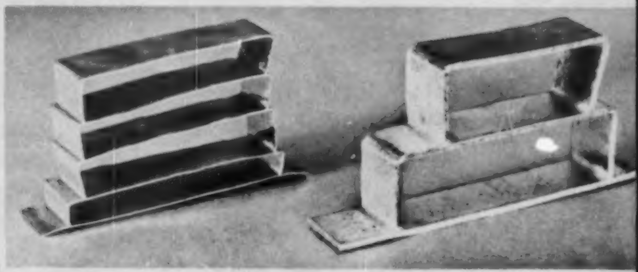

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materials

Synthetic diamonds larger than a carat have been produced by General Electric Co., Schenectady, N.Y. However, so far the big man-made gems are too dark for milady's jewelry and lack the structural strength needed for industrial use (see photograph No. 2). It is possible to make 1/10-carat diamonds strong enough for industry, but even this size is much larger than any synthetic stone now available commercially. Because of the uncertain conditions in the Congo, the major source of natural diamonds, man-made gems have taken on added importance.

Controlled-porosity bodies can be produced by pressing and sintering, by using spheroidized particles of many types of materials now available from Thermal Dynamics Corp., Lebanon, N.H. In addition, this technique increases the flowability and packing of the particles.

new processes

A new process for joining copper parts has been announced by Chase Brass & Copper Co., Waterbury, Conn. A special coating is applied to copper which, when heated to 1700-1800 F, forms a diffusion-homogeneous bond to any copper or high-copper alloy held in good contact with it. The process is expected to facilitate the automation of joining operations and bring about production economies.

Possible applications include electric motors, generators, transformers, heat exchangers, and various electronic devices. It is claimed that the bonded joint is as strong as the metal joined, and that the bond is suitable for use where the joint must be vacuum tight.

For the assemblies shown in photograph No. 3, the strip surface was coated with a bonding agent, but no coating was applied to edges.

Achievement of laser action (light amplification by stimulated emission of radiation) with about one-tenth the power formerly required has been announced by Raytheon Manufacturing Co., Waltham 54, Mass.

More efficient direction of input light has accomplished the power

savings, which may speed the highly desired development of a continuous light beam for "light radar" and other applications. Also, the smaller power supply needed will hasten its future use in aircraft. In Raytheon's new laser (photograph No. 4), a ruby rod at center and a flash tube below are positioned on focus lines of an elliptical reflector.

Leads as fine as 0.0001-inch in diameter can be welded with a new ultrasonic welding and soldering unit produced by Cavitron Corp., Long Island City, N.Y. The equipment is capable of joining a multitude of shapes and types of material such as 0.0004-inch-diameter gold wire, 0.002-inch-diameter nickel leads, gold wire soldered to gold-plated silicon or 0.003-inch aluminum foil, 0.0015-inch gold-gallium alloy, and 0.001-inch copper-nickel alloy with 28% indium.

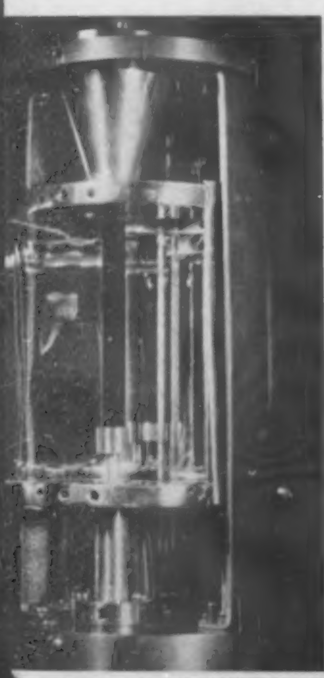
now available

A new solid-state operational amplifier is available from George A. Philbrick Researches Inc., 285 Columbus Av., Boston, Mass. The amplifier features low-current drain (10 milliamperes), high-input impedance, and high gain.

A battery-operated, three-channel miniature tape recorder is available from Precision Instrument Co., 1011 Commercial St., San Carlos, Calif. (See photograph No. 5.) The recorder operates at 1-7/8-inch-per-second tape speed. Frequency response is essentially flat from 100 to 5,000 cps, with negligible flutter and wow (a condition resulting from uneven tape speed). Signal-to-noise ratio is better than 30 decibels.

A precision balance for weighing objects up to three milligrams, and in the range up to 50 grams, has been introduced by Federal Pacific Electric Co., 50 Av. L, Newark 1, N.J. (See photograph No. 6).

U.S. Radium Corp., Morristown, N.J., has brought out the Ionaire, a compact desk- or table-top device capable of generating 1-billion negative ions per second (photograph No. 7). Medical research has shown that a sufficient number of negative ions in the air will reduce nose and throat congestion and make breathing easier.



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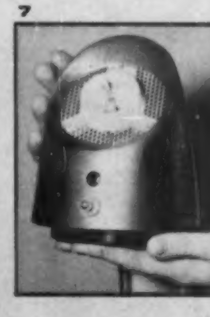
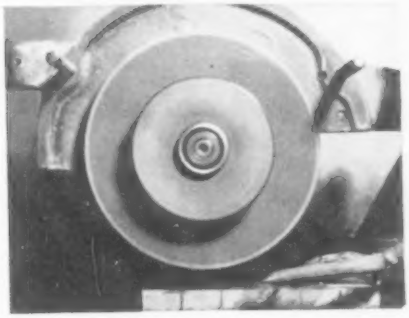


A specially developed type of grit enables resin-bond diamond wheels to grind rapidly and efficiently.



A diamond abrasive wheel is tested at the Diamond Research Laboratory by surface grinding a block of tungsten carbide.

Staff member counts number of diamond grit particles which appear on the screen of a microscope. This instrument was especially developed for checking the shape of diamond grit.

Laboratory drilling machine tests the efficiency of diamond drill crowns in granite.

IF YOU ARE INTERESTED

in the Laboratory's work, please fill in this coupon. You will receive a copy of this attractive booklet outlining the function and the findings of the Diamond Research Laboratory.

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MACHINES

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DECISIONS

bionic machines

-a step toward robots

by **Dr. Peter M. Kelly,**
staff scientist, Aeronutronic Div. of Ford Motor Co.

With more than 12 years experience in radar and communications electronics, Dr. Peter Kelly has been responsible for design and construction of instrumentation radar for Navy missile testing, and also has conducted studies on other radar problems connected with missiles and earth satellites. A Cal Tech PhD in electrical engineering and physics, Kelly recently shifted his position at Aeronutronic, from radar department head to staff scientist, to devote full time in development of cognitive radar techniques.

ROBOTS — machines with human-like abilities for discrimination and judgment — have stirred the imaginations of scientists for centuries.

The robot dream has been moving continually closer to reality with modern developments in electronics, and during the last 15 years designs for preliminary devices have been attracting more and more attention. Coupled with the fascination of robots have been practical needs, especially for military applications.

In many fields of electronics — servomechanisms, digital computers, radar, communications, navigation — weapons systems are becoming obsolete almost before they can be put into use. More adaptable electronic systems are needed, planned along the governing principles of biological systems. Such proposed electronic systems are labeled variously as bionic systems, bio-computers, or simply self-adaptive systems.

A strong demand for the biological approach to electronics has arisen because research results indicate that initial designs may be feasible, and because the defense department needs electronic controls, computer systems, and sensor networks which are both highly advanced and sufficiently flexible to adapt to changing definitions of stated tasks.

Evidence of progress includes a "neuron that learns" at Ford Motor Co.'s Aeronutronic Div.; a similar unit at Stanford Research Institute; the Perceptron project at Cornell Aeronautical Laboratory; and research studies on the learning process at most leading electronic firms, especially IBM, Melpar, GE, and RCA.

A probable influence toward the current surge of activity in bionics was last summer's Moscow Conference on Control Systems, at which American scientists saw Russia's preoccupation with self-adaptive machines.

Over the threshold of money

Another factor, difficult to evaluate, is the financial "threshold effect" — the doorstep in national affairs across which a new activity must be pushed by enough influential people convinced of its merit. That this threshold just recently was passed for bio-computers can be seen in the Wright Air Develop-

ment Div. bionics budget of more than $1-million for 1960-61, in contrast with the previous year's $40,000 allocation.

Highest of today's hopes are centered on development of true robot systems. But the more conservative observer may see only limited possibilities — an increasing number of separate results, so far uncorrelated, which show the feasibility of adding self-adaptive features to electronic systems.

In discussing bionic systems, it indeed is difficult to hit the desired tone of restraint-tempered enthusiasm. Scientifically respectable evidence for success definitely exists. Yet, potential of the field is so staggering — ranging as it does from recognition radar and robot space navigators to mechanical gardeners — the actual work accomplished looks extremely meager.

But as biological electronics becomes more and more fashionable, it is inevitable for all new systems to be designed along bionic lines, just as it was fashionable in earlier days of semiconductor development for new system proposals to contain plans for transistorizing electronic units. Currently for example:

- Aeronutronic's PACM-FM telemetry system, using a combination of analog and digital techniques, is influenced by similar features of biological systems.
- Bell Laboratories' new N-Path filter is effective because it contains a large number of paths between input and output, reminiscent of nerve networks.
- General Electric's adaptive filter will work in a prosaic communications system, but in itself is influenced by biological principles.

Thus bionics is growing rapidly with no clear line of demarcation between it and electronics in general. This is a natural course, since even present electronic systems often have been described in terms of biological systems (giant computers have been compared with human brains; conversely, we say that bats have built-in sonars).

Bionic byproducts

Bionics research also should produce useful byproducts that can be put to use immediately as part of existing electronic systems. These new products will break down the boundary between old and new electronics research.

The rapidly developing situation, with implications for design of electronic systems of all types, means that some electronic firms will find themselves in favored positions. Such is the case, for example, in companies with vested interests in bionics techniques through past in-house or government-sponsored research. Some firms have well-recognized skills in closely related fields such as digital computers or sophisticated communications systems. Others have broad system responsibilities under which they can justify developing bionics capabilities. Still others have developed miniature components or microminiaturization techniques.

(Miniaturization is important, for bionic systems are characterized by decentralized structures requiring large numbers of very small parts, as does the animal nervous system. To keep the electronic analog of an animal system reasonably small in size calls for a high order of microminiaturization.)

Bio-computers have been defined as machines capable of recognizing, abstracting, learning, and generalizing. (If this sounds like "thinking," the reader may wish to refer to a more detailed discussion in "Automata" in the Spring, 1959, issue.) All four functions necessarily are closely interrelated.

Recognition: telling an A from a b

Recognition, as has been emphasized by a number of scientists in this field, implies that learning has been accomplished. If a bio-computer is organized so that a bell rings each time a rigidly prescribed pattern—such as a certain size and type letter A — appears in the sensory field, then it can be said that the machine recognizes the letter A.

A coding, or preorganization, section of the machine exists to detect certain points of interest in the pattern, such as geometric features. This section, containing components variously referred to as "translational and interpretative" (T & I) units, "property filters," or "cognitive demons," generally will be predesigned with no self-adaptive features. (Usefulness of the units probably will lead to their rapid development for such byproduct applications as character recognition and target identification.)

Machine recognition basically is achieved through the use of many sensors, operating together much like the rods and cones of the human eye, to describe a multi-dimensional pattern. In most cases, useful recognition will involve a reduction in dimensionality of the pattern within the bio-computer in order to group many different patterns into a relatively few classes.

Abstraction: whales and submarines

This reduction in dimensionality is called abstraction. The type of abstraction desired dictates the internal structure of the computer. Once the abstraction process has been determined, the machine's abilities thereafter are limited to this process. For instance, the machine may be capable only of those logic processes necessary for distinguishing a whale from a submarine, if this function is sufficiently useful to justify development of a special machine.

More interesting, however, is a machine which would recognize a variety of objects and "mentally" experiment with the sensory input signals they receive so as to seek out familiar shapes. Such a machine would operate by "free abstraction," since it would try many methods of abstraction in attempting to recognize the pattern it is given.

Free abstraction leaves so much creative freedom

to the machine and is so much more advanced than other methods that it probably won't be represented in early machines developed for tactical military operations.

Dr. Peter H. Greene of the committee on mathematical biology, University of Chicago, has suggested an approach to the "free abstraction" problem. In his plan, T & I (translational and interpretative) units are designed so that for a simple pattern within their capabilities they yield a large signal on only one of their many output terminals, and small signals on all others. Thus, one T & I unit yields a "sharp" signal for circles, another for the color red, etc.

A lack of sharp signal on the "circle unit," however, may not mean that circular shapes are absent; it could mean only that interfering patterns have obscured such shapes. Thus, subtraction becomes a form of abstraction, and is needed to increase possibilities for recognition. A variety of subtraction techniques must be tried as the machine seeks recognizable patterns.

Learning: free and soldered

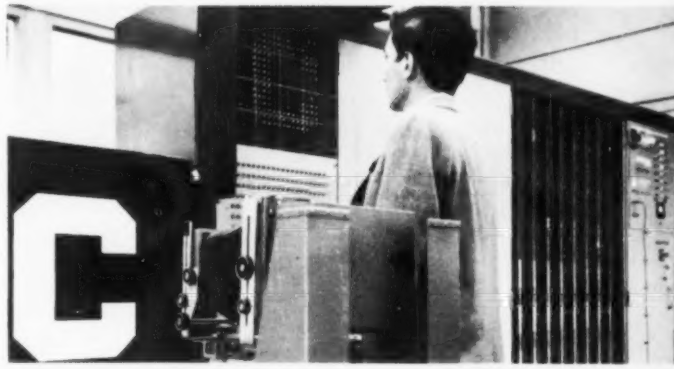
Learning or self-adaptive features will be concentrated in the internal logic section of the bionic machine. If the machine is wired to recognize an "A," then learning already has occurred at the time the technician soldered the wires together. The process might be called "soldered learning," and is the least flexible type of machine learning.

Connections can be made, however, in which resistivity can be varied. For such a condition, many connections are wired into the internal logic of a biocomputer and their resistivity is adjusted to obtain desired results. If adjustments are made under direction of a corrective network, the process is called "forced learning." If adjustments are allowed to take place in a somewhat random manner, the process is called "free learning."

Drawing No. 1 illustrates the approach taken to learning in the Cornell perceptron. The nomenclature in the sketch is that of the Cornell reports. "S" denotes sensory unit; "A" an association unit, which basically is a majority logic element; and "W" the variable weighting connection to the "R" or response unit, which also is a majority logic element. The combination of variable weighting connections plus the majority logic element makes up a neuron.

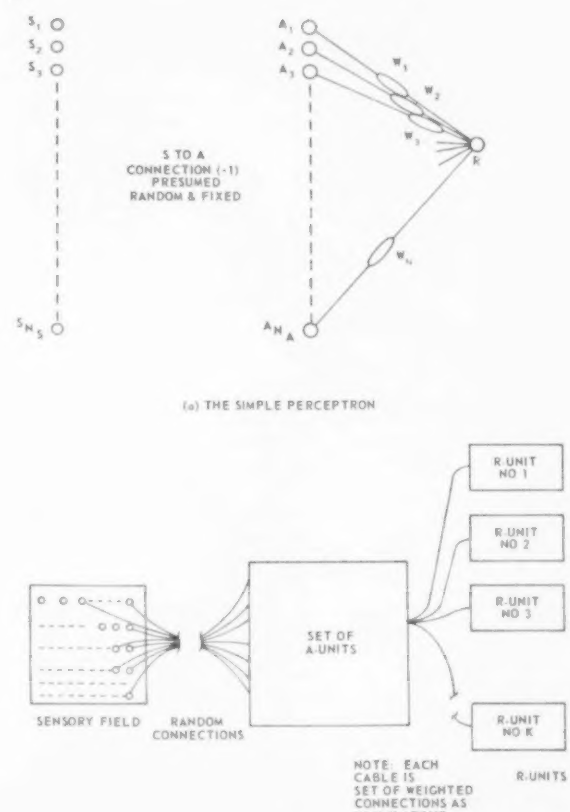
(The electronic neuron, which parallels the human neuron, yields one output if the sum of the inputs exceeds a certain threshold, and another output if the threshold is not exceeded. As the weights of the inputs are varied, the classes of patterns to which the neuron responds vary in a corresponding manner.

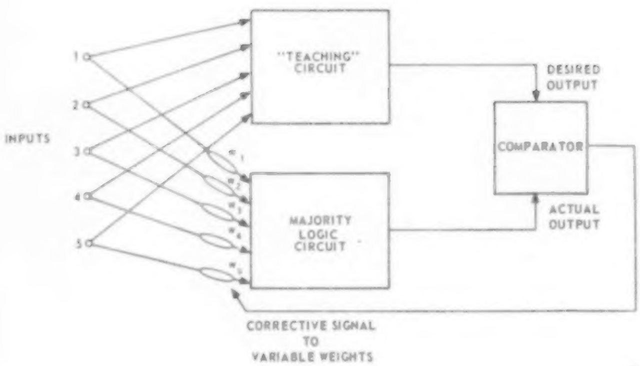
(The neuron is the building block of the adaptive portion of a bio-computer, and millions of such units would be required to approximate the performance of an animal brain. Hence the vast effort at many



MACHINE RECOGNITION *of the letter "C" by Cornell's perceptron is demonstrated as the computer's photo-cell "eye" looks at the letter pattern, lower left, and activates the display area being studied by a Cornell scientist.*

1





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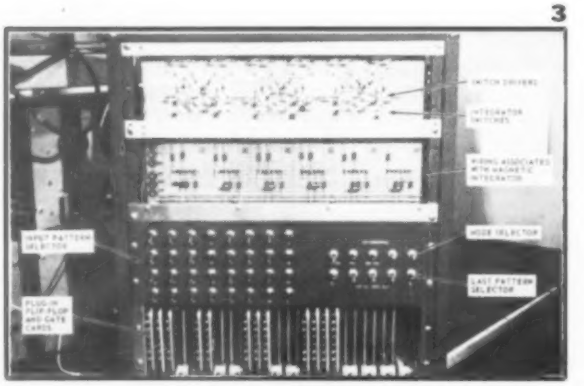
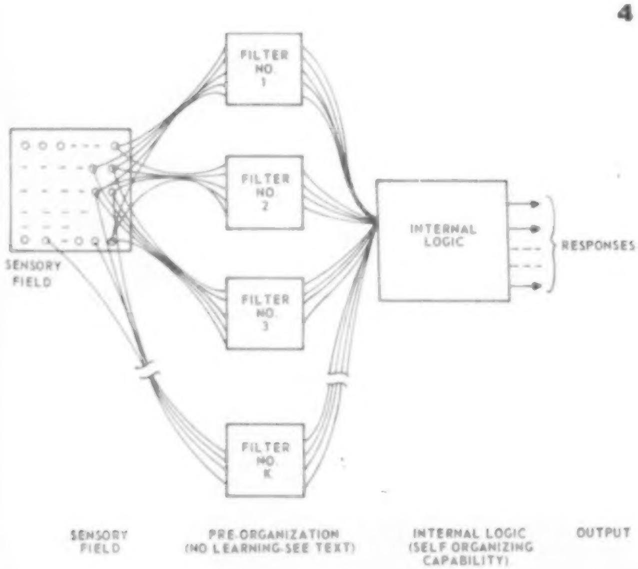


LEARNING MACHINE *built by Aeronutronic, above, includes the experimental "neuron that learns" and other equipment shown in diagram No. 2, plus input pattern-generating circuits.*

4



laboratories toward developing and miniaturizating such units.)

In the perceptron, no coding sections such as T & I units are used, and all such functions must be developed as part of the internal logic. The connections are completely random from S to A units. The number of these random connections supposedly is sufficient to realize all possible interpretations of the input pattern. Interpretations are gathered into appropriate R units by adjustment of the connection weightings during the learning process.

The perceptron concept, represented in hardware form by Cornell's 400 S-unit and 512 A-unit machine, is of unusual significance. The random connection approach has parallels in biological organisms and, if successful, offers possibility for obtaining connections by natural reinforcement processes. This would avoid the need for extreme microminiaturization by eliminating the interconnection requirement.

Perceptron criticism has been directed mainly at its inability to generalize. Significant perceptron activity has shifted recently from Cornell Aeronautical Laboratory to the university's campus, where the working group includes Dr. Mark Kac, mathematician, and Dr. Frank Rosenblatt, psychologist and perceptron inventor. This group already is showing that present perceptron deficiencies can and will be overcome.

A neuron that learns

The neuron in diagram No. 2 includes the teaching circuit and illustrates the neuron-learning experiment at Ford's Aeronutronic Div. No. 3 is a photograph of the machine built at Aeronutronic, which includes not only the neuron but all the other equipment in diagram 2, plus the input pattern-generating circuits.

Several investigators have suggested the use of preliminary units, or filters, to simplify the recognition problem. A bio-computer organized along these lines is shown in diagram 4. These filters are an example of soldered learning, which is rigidly limited.

At the other end of the scale is free learning, which involves neither the pre-coding of drawing 4 nor a teaching circuit as in No. 2. Some preliminary research has been done on the process of free learning, notably by Dr. George R. Cooper, Purdue University department of electrical engineering. Adaptive-control systems such as those developed for aircraft exhibit a type of free learning.

Dr. J. R. Singer, professor of electrical engineering, University of California at Berkeley, has developed an input filter, or T & I unit, to recognize certain simple geometric shapes regardless of size. Thus, general criteria of performance can be established within which free learning may be accomplished.

Teaching a machine to classify every possible variation of a pattern, correctly and in detail, in-

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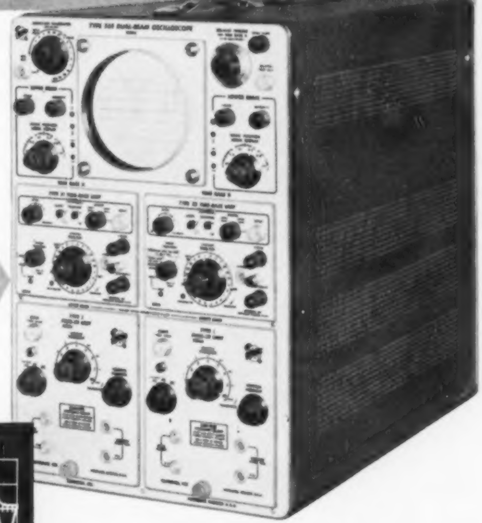

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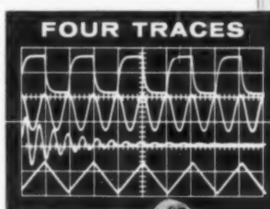

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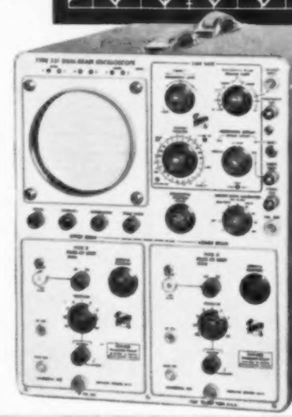

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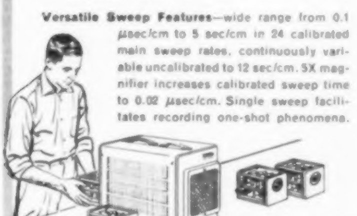

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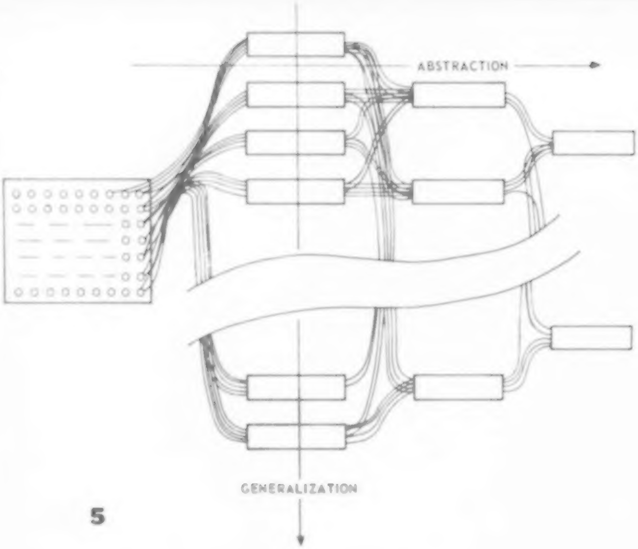

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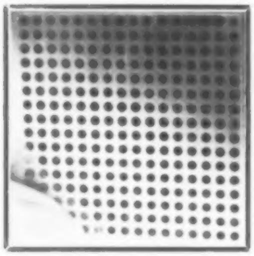

MAGNETIC MEMORY *(top photo) for computer at MIT Lincoln Laboratory has circular memory elements of Permalloy film 750 angstroms thick and 1.6 millimeters in diameter. Lower photo shows memory developed by International Computers and Tabulators Ltd., England. Using gyralloy, a new alloy, the film will store 2,500 bits on a 4 x 6-inch plate.*

volves a forbidding amount of labor. It is highly desirable that the mechanical system be able to generalize what it has learned, as does the biological system.

In its simplest form, generalization merely is the recognition of a noisy or blurred pattern as being of the same class as a corresponding clear pattern. It is reasonable to expect that this sort of generalization will come about due to the use of majority logic elements in bio-computers.

Recognizing displaced or rotated patterns is a more serious problem and requires that the machine be aware of possible relationships between patterns in different portions of the field. For example, if the machine has learned to recognize the letter "A," it ought to have the inherent capacity to recognize, without further instruction, an "A" with rough edges, an "A" in various distorted shapes, an "A" on its side or upside down, a small-letter "a" and other variations of the basic pattern.

One of the chief problems with character-recognition machines has been in providing this capacity to generalize. The feature is even more imperative for machines which must function in a three-dimensional world.

The recent work of Rosenblatt, Dr. H. D. Block, Dr. B. W. Knight Jr., and others at Cornell, taken in conjunction with the work of Uttley in England a decade ago, indicates some means of obtaining generalization in a bio-computer by use of cross-connections in internal logic, as illustrated in diagram 5. This cross-connection feature may be incorporated effectively by increasing the logic depth of the machine and having connections from widely separated points in the sensory field meet at the same logical elements.

An avalanche of progress

As previously mentioned, there is no clear-cut line of demarcation between electronic systems in general and bio-computers. The first large bio-computer need not approximate human characteristics in all detail. The first machine should be a system advanced enough to justify the investment, but orthodox enough to insure success. The very existence of one or two such systems will serve as a catalyst to hasten development of additional systems.

Progress in bionics probably will not be a slow gradual development, such as usually is expected with new concepts. It is more likely that major progress will come in the nature of an avalanche, with little discernible motion until the avalanche occurs.

The primary reason is that there literally is no such thing as a small bio-computer, any more than there is an intelligent man with a 100-neuron brain. Modest efforts cannot be expected to yield dramatic results. Further, construction of the first bio-computer will remove much of the present reluctance to build such units, and rapid and broad activity can be expected to follow. ■

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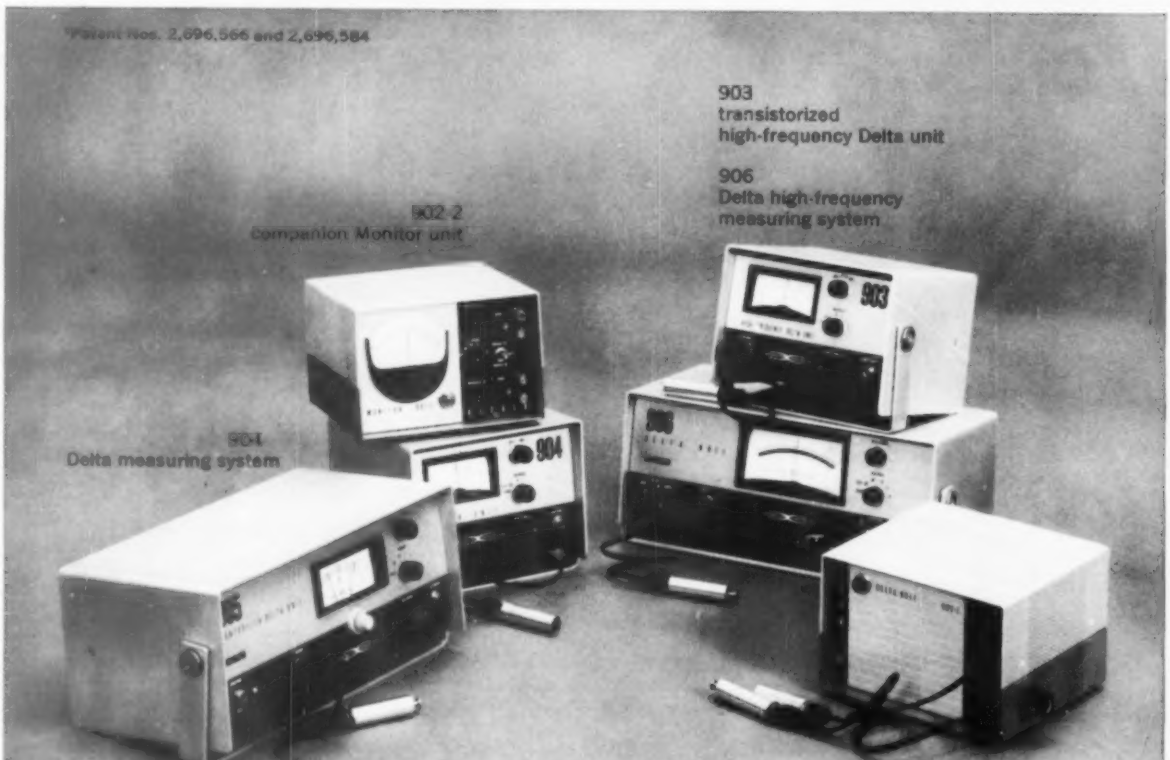

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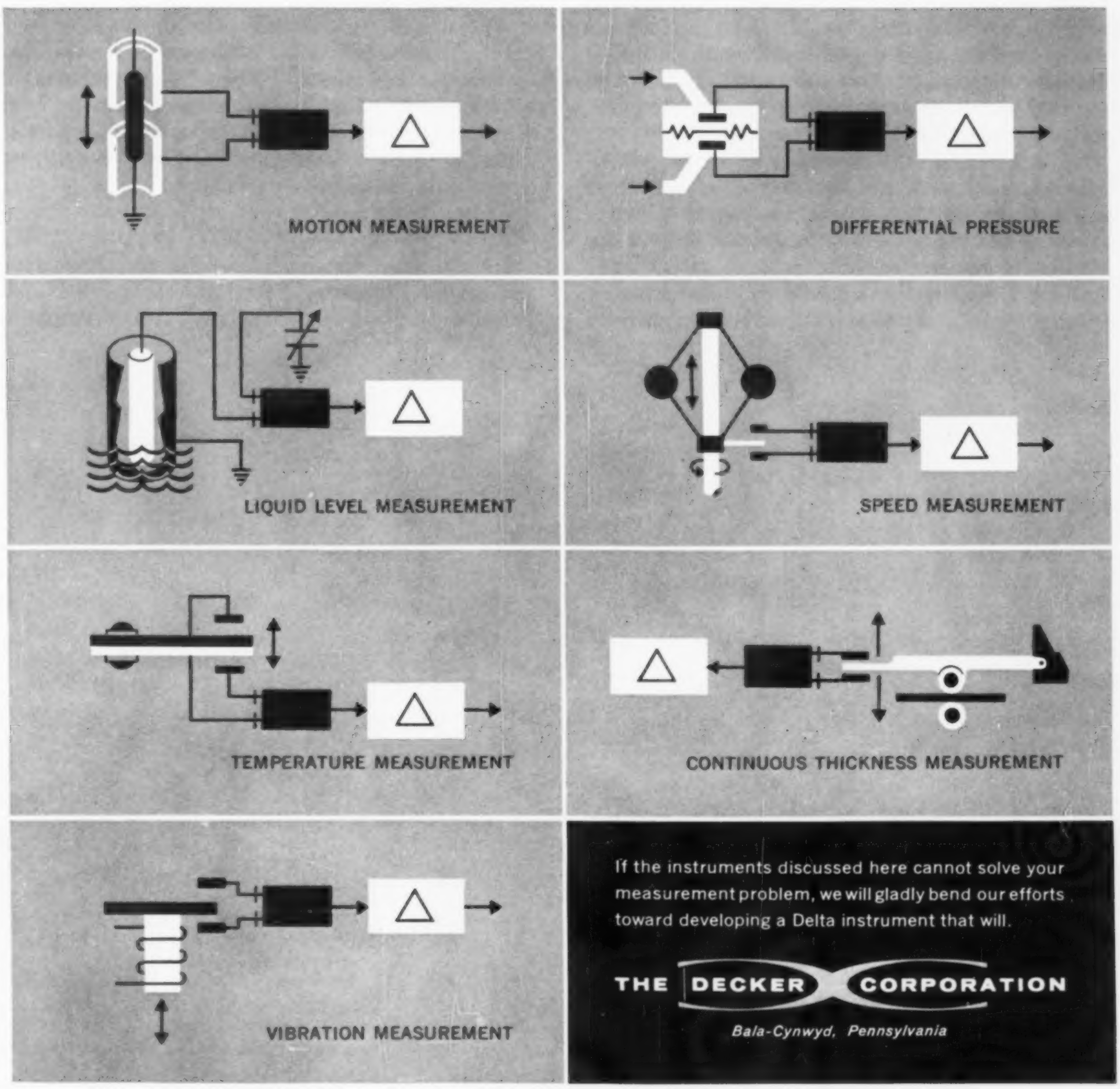


management machines

-a systems approach

UNDOUBTEDLY THE MOST DIFFICULT aspect of establishing decision machines for management is the lack of formalized objectives in business. The old cliché of profit being the primary objective of a business enterprise gradually is disappearing.

From the systems viewpoint, consideration must be given to several objectives. However, not all businesses have the same objectives, since they depend on the willingness of management to take action in the face of uncertainty and with inadequate information.

With the increased capability of computers to provide information in a form useful for evaluating many alternatives, we quickly are approaching a more meaningful basis for establishing realistic objectives. Illustrating the problem, for example, management might state as an objective the attainment of an increased share of the market for a given product. Yet an economic analysis of the factors involved might prove this objective to be unrealistic. It is possible that for a given capacity, capital structure, distribution system, etc., costs easily could exceed the value gained from obtaining a greater share of the market.

The difficulty in formalizing such objectives arises from the fact that there is no simple method for evaluating the impact of objectives on a complex system. And without this evaluation, the objectives may be meaningless. For this reason, computer simulation seems like a suitable approach to the problem of specifying meaningful objectives.

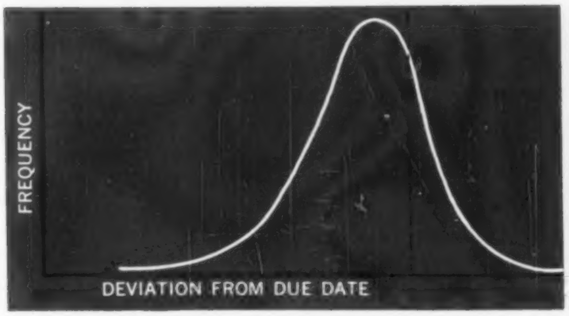
Beyond data processing

The same argument applies to design of the system itself. Alternative designs should be compared prior to actual use. In business systems, a computer

by **Dr. Alan J. Rowe,** *manager, industrial dynamics research, Hughes Aircraft Co.*

Before joining Hughes, Dr. Alan Rowe directed management control systems research for Systems Development Corp. He also has been an assistant professor at UCLA, where he received his PhD in engineering, has served on the faculties of Syracuse and USC, and has been a research consultant for General Electric.

EXECUTIVE CONSOLE *model of automatic memory system, by Lockheed, would speed decision-making in large organizations as much as 10 times.*



can become an essential instrument for such testing. However, unless formalized decision rules are available, the computer merely acts the role of a data processor.

On-line computer control actually is a form of automated decision making. On the other hand, the computer also can be used to present information to managers as an aid in decision making.

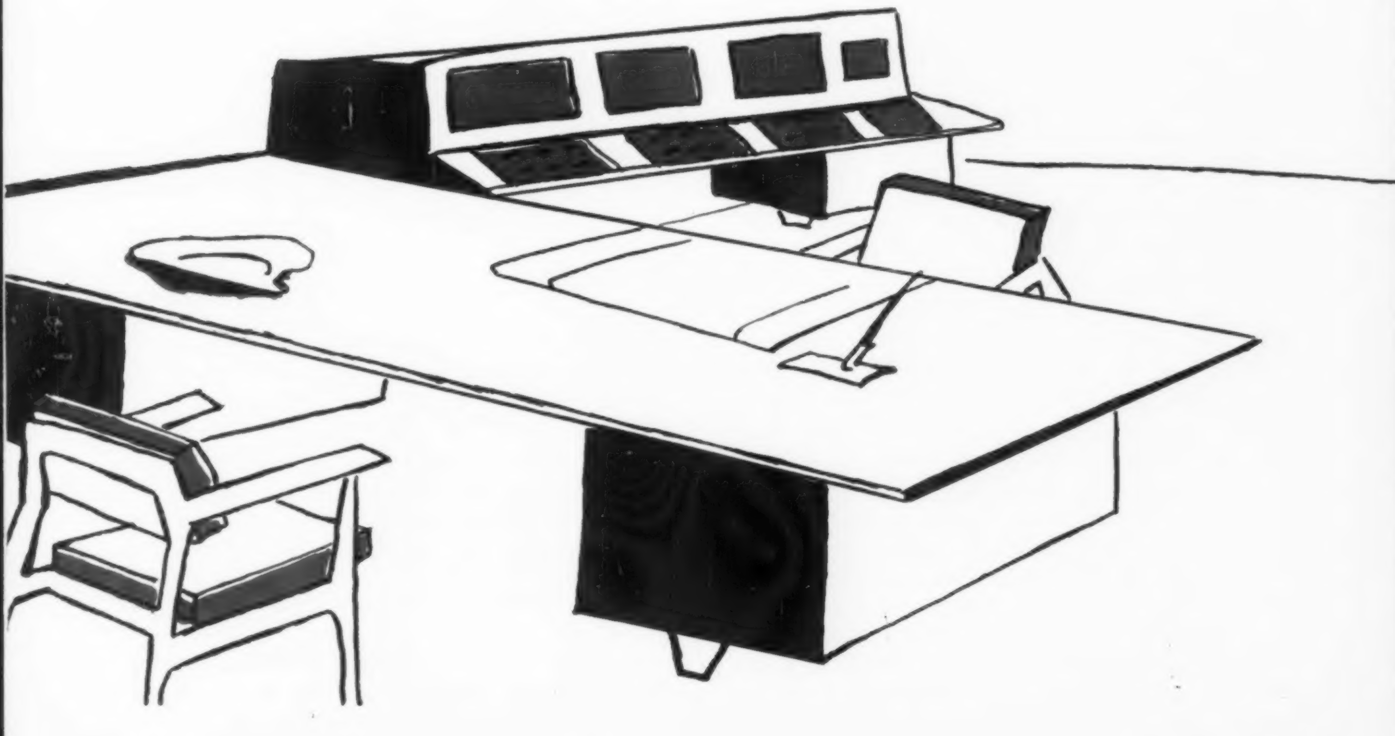
Unfortunately, the majority of decision rules developed in business to date give no consideration to the systems aspect of the problem. For example, rules for optimal inventory do not consider the cash position of the company at the time an order is placed. As an alternative to formalized decision rules, computer simulation can be applied in a find-it-yourself approach to problem solving. Thus, if the cash position were low, a simulation run could be made to predict the effect of alternative solutions.

The problem with rules that might be established for management machines is the difficulty of evaluating a system having a large number of variables. However, although the outcome of a particular combination of variables is difficult to predict, the results often form a reasonably consistent statistical distribution.

Thus, when jobs are processed in a factory, for example, the completion of any specific one cannot be predicted, nor can the sequence in which other jobs will be completed. Yet it is possible to predict the overall probabilities of completing jobs. This can be depicted as shown in the diagram above.

In a like manner, problems involving a large number of variables in management controls can be treated from the statistical viewpoint.

The use of a combination of formalized decision rules and computer simulation techniques for man-



agement controls opens up interesting new vistas. In effect, it would be possible to have detailed, realistic monthly or quarterly forecasts (of labor, for instance) instead of daily or weekly forecasting.

Also the problem of annual budgeting could become more meaningful. Instead of waiting until year's end to discover by how much a budget missed its mark, the business could respond to changes as they occurred. Of course this presumes that flexibility has been designed into the system to permit rapid response to the changing environment.

The research question

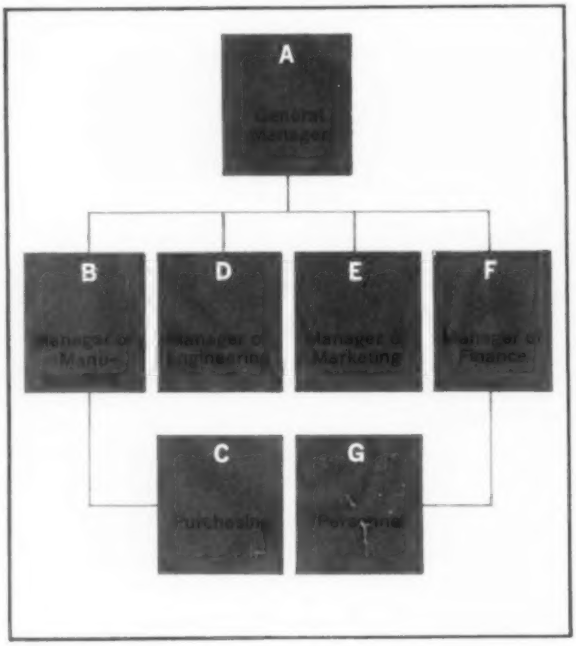
Research in management decision machines should have as one of its objectives the study of real-time problems such as these. A basic question in management decision machine research is the scope of the problem under consideration. Most research of this type today is component or subsystem control. A lack of concentrated effort exists, from the systems viewpoint, on the business as a whole. Therefore, the approach proposed is to study the entire business as a logical system.

As in any research program, the starting point should be a survey to establish the state of the art. In addition, a research plan should include:

- *A well-formulated model of the characteristics and structure of management control systems.* The model, designed to use a large, high-speed computer, should have the ability to examine effects of changes in management controls on system performance. For example, how would a change in an organization affect information flow rates, time lags, bottlenecks or queuing (an accumulation of operations waiting to be performed) in a given system?
- *A general-purpose computer model for simulation.* A network representing factors such as decision areas, information channels, and authority relations can be used in the model. The information flow, feedback loops, and computed scores would be used in the model to establish the structure for decision making.
- *A study of the behavior of the computer model to gain insight into the problem and validate experimental conclusions.*
- *Design of decision rules in management controls.* Management consultant Peter F. Drucker, in his book, *The Practice of Management*, has clarified the need for formalized decision making in management.

Rationality versus blind gamble

Drucker speaking: "*It is not within the decision of the entrepreneur whether he wants to make risk-taking decisions with long futurity. He makes them by definition. All that is within his power is to decide whether he wants to make them responsibly or irresponsibly—with a rational chance of effectiveness and success, or as a blind gamble against all odds.*



"*The process is essentially a rational one and the effectiveness of the entrepreneurial decisions depends on the understanding and voluntary efforts of others. Thus the process will be more responsible and more likely to be effective the more it is a rational, organized process based on knowledge.*"

Some ramifications of management decision making to be considered in utilizing computers are: information required to make decisions: where decisions are made and by whom; the number and type of decisions made at various organizational levels; response rate required for decisions after information is received; time actually taken to make the decisions; induced delays in information flow due to decision making; errors (noise) in the decision-making process; and others.

How can these criteria be modeled on a computer?

A simplified hypothetical organization will serve as an example of an approach to modeling. The diagram above represents some of the typical functions found in a business enterprise. Department heads B, D, E, and F report directly to the manager A. Purchasing C reports to B and personnel G reports to finance F.

These are similar to conventional authority channels. But they do not represent the dynamic interrelationships of these functions. A simulation model, on the other hand, can portray various alternative relations as a function of time, urgency, or decision criteria.

For instance, let us represent this conventional organization chart in the form of a matrix shown

	A	B	C	D	E	F	G
A							
B	X						
C		X		Y			
D	X						
E	X						
F	X						
G						X	

	A	B	C	D	E	F	G
D1	1	2		2	2	2	
D2		1		2	3	4	
D3		1	2				
D4	0				1		
D5		0					1
.							
.							
.							
Dn			1				2

above, center. Thus, as was shown in the diagram at left, B, D, E, and F report to A, and C reports to B.

An organizational matrix

Note the ease of indicating where all the persons report by merely placing Xs in the matrix, and also the possibilities of modifying these relationships. Informal or secondary channels can be represented by other letters, such as Y. For example, the fact that purchasing may report informally to the engineering manager is shown by the Y.

In a similar manner, the matrix format can be used to indicate information flow, material flow, etc. For example, a formal information flow pattern might be as shown above, right. The numbers inside this matrix indicate the sequence of flow through the organization, as well as the originator of the document. The letters correspond to the conventional organization chart shown first. Special codes such as O can be used to indicate that the document or data originated outside the system.

The letters alongside the matrix, D_1 through D_n, are the coding to identify specific information—a telephone call, a sales report, customer order, absenteeism report, etc. In this way, the communications network can be formalized and an informal information flow also can be incorporated into the matrix.

This matrix arrangement also can be used to represent raw data or system status. Referring to the information-flow matrix, the manager may issue a directive D_1 to his department heads (who are presumed to receive the communication simultaneously). In turn, they may be expected to take appropriate action. In effect, this directive causes a decision to be made by each of the department heads. The basis for their decisions and the consequent actions all would be part of the computer model.

Another type of information flow is shown opposite D_4. Here the general manager receives information on the market position of the company and forwards it to the marketing manager. However, the dynamics of this situation must be represented within the computer model to attain realism.

For example, how soon is the information transmitted? How long is it before the marketing manager takes appropriate action? These are some typical questions that can be studied with the simulation model.

Still another form of information is shown opposite D_5. The manager of manufacturing notifies personnel that there is a shortage in a given skill category and that hiring should proceed. The zero in the box opposite D_5 now is used to indicate that this information is a result of the system performance.

Thus, as data are summarized and made available at various points, they become inputs to the information flow. The kind of data, manner of summarization, and frequency of reporting all would be part of the simulation program. By providing for variation in the pattern of information flow, it would be possible to examine the effect of reporting on system performance.

Events that trigger decisions

It also is possible to use the occurrence of specific events as the condition for decisions to be made. Thus, as systems change, certain events become critical and trigger information flow to decision makers.

Suppose that a part has completed its processing in the factory and is ready for assembly. When this state of completion is reached, the information could be transmitted immediately to various locations where decisions are made.

For example, the information processing system may be such that at the end of each day production control is the only department notified as to which parts have been completed. The actions of this department, in turn, depend on the status of mating parts. Therefore, a logical procedure as a basis for decision making might be made:

- Is part A complete? Yes.
- Is part B complete? Yes.
- Is part C complete? No.

If the assembly requires all three parts, then the answer—yes, yes, no—would lead to a different decision than three yeses. This can be represented as follows:

- Part A has been completed. What decision now should be made?
- Determine completion status of mating parts.
- If all three are completed, proceed to assembly.
- If any component is not completed, place parts into an accumulation area.
- Repeat the check on status of mating parts after a suitable time interval.

A simplified search technique

In the computer model, a search would be made to determine when the decisions are carried out. This search technique can be simplified by using the logical characteristic of computer operation.

For example, two triggering conditions might initiate the decision process. The first condition would be a result of a change in the system status; the second condition would be the result of a formal document requesting the purchase of some raw material.

A logical comparison of conditions and requirements implies a yes-no type of response. An important advantage of this method of comparison is that computers operate in a binary, or yes-no, mode so that this approach simplifies computer programing as well as avoiding ambiguity.

This logical format for representing the decision-making process is especially useful in studying problems involving a number of interacting elements. It is the computer's ability to update and store information that permits exploration of these considerations in detail.

Time lags in information flow

A significant aspect of the control problem is the time phasing for contingent decisions. The flow of information can introduce time lags into a system as a result of queuing effects.

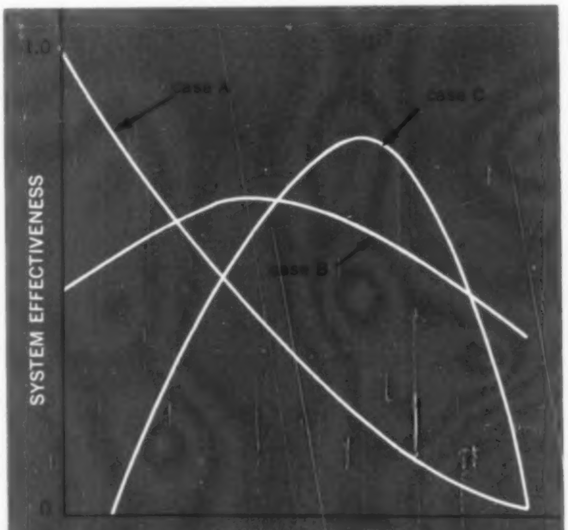
In a sense, information flowing through a number of decision makers is comparable to tasks performed in a factory or cars flowing on the highways. For example, if the decision maker is viewed as a processing center, the rate of arrival of decisions and the time taken to make each decision will determine the average delay. Where priorities are given to the various decisions made, it is possible both to improve effectiveness and reduce delay times.

Another means of reducing delays is to have alternative channels for given decisions.

Another is to filter or screen decisions to reduce flow time through the system. However, this method of treating decision making might lead to radical changes in organization structure and hardly could be tested initially in a real-life environment. These and related questions can be examined readily by computer simulation.

The formal and informal information channels in an organization, and the points at which decisions are made, directly affect system performance. Graphically, the system effectiveness as a function of speed of response might appear as in the diagram below. That is, for a given type of decision, organization structure, and cost, there are alternative response rates which are optimal.

For Case A, shown in the diagram, the faster the response, the greater the system effectiveness. Any time lags would hamper performance seriously. On the other hand, rapid responses in cases B and C



are not nearly so critical. Thus, the information flow rate is a key parameter in system design.

Of course, speed of information flow is not a sufficient criterion of usefulness. Information, in an understandable form, and free from errors, is also a significant factor. For example, the exception principle of management is concerned with minimizing the quantity of information necessary for decision making.

In a like manner, system performance information can be summarized into more meaningful form for decision making. An important problem is determining what information is required, in what form, and with what speed, in order to make effective decisions and provide feedback for control.

A more thorough analysis of the kinds of decisions made should yield insight as to where the computer can aid the decision maker. Routine decisions involving a large quantity of data can be automated most easily. Complex decisions involving judgment and analysis could use computers to digest information, evaluate alternatives, and test key parameters as aids in decision making.

The span of supervisory control

Another aspect of organization which could be explored by computer simulation is the span of supervisory control. If a supervisor's job is analyzed, it is soon apparent that a certain percentage of his time is spent in direct contact with subordinates.

Time spent during contact with subordinates would follow some distribution such as shown below, center. The shape of the curve and spread or variation would depend on the characteristics of the particular supervisor, the level of persons being supervised, and the type of work performed.

Thus, rather than a specific number of persons that can be supervised, the arrangement of work content and number and kind of decisions will have a direct bearing on the problem. Since the supervisor is a decision processor, an economic span of control could be determined as below, right. If the supervisor were always available (no subordinates), there would be a high idle cost. However, if there were too many subordinates, decisions could be delayed due to the supervisor being unavailable. This would lead to a high waiting cost.

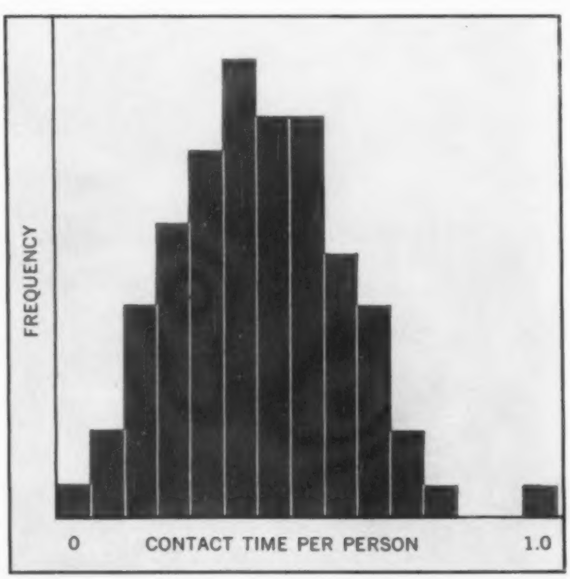
Taking the systems viewpoint, the correct span of control would consider the cost of delays in decisions on the entire business. Since the waiting or queuing effect increases exponentially, it appears that there is an optimum availability of the supervisor which can be related to the span of control.

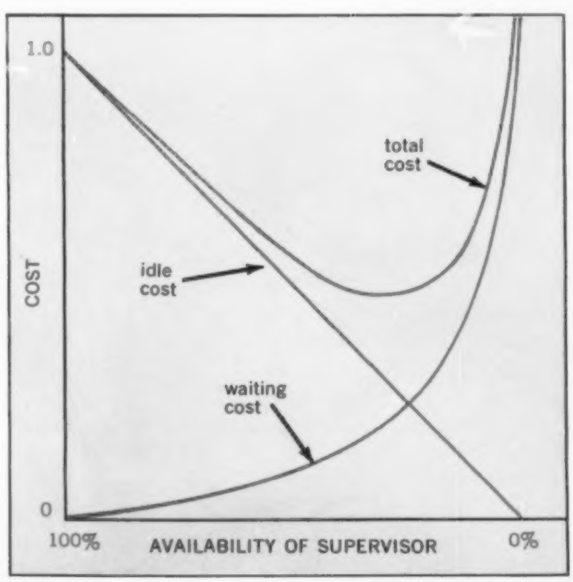
Thus, detailed considerations of business systems behavior are necessary adjuncts to studying management controls. Such considerations become especially important where control is considered the means for assuring compliance with desired system behavior.

Rather than establishing arbitrary bases for component control such as fixed budgets, turn-over ratios, return on investment, etc., optimum total system performance should be the objective. Optimum system performance can be defined in terms of the resources available, specified goals, allowable risks, and environmental factors.

In essence, the systems approach can result in an overall upgrading of the many facets of a business. ∎

For more information on management control, see *Management Control Systems* (John Wiley, 1960). This article is based on the author's chapter in that book.





education machines

-a trend toward automated teaching

Automated training may be the answer for acute teacher shortages, as scientific ad

AUTOMATED EDUCATION is the inevitable corollary of automated production, and probably the only effective answer to acute teacher shortages in schools at a time when our population is expanding and scientific discoveries require increased teaching.

As millions of industrial machines become more intelligent, so must millions of workers. The ill-fated physical competition between John Henry, the "steel drivin' man," and the relentless steam spike-driver is not likely to be repeated on the level of routine mental tasks. It should not come as a surprise if unions very shortly begin to demand skilled training and placement for every unskilled worker displaced by automation, as a provision of any new contract with a large company.

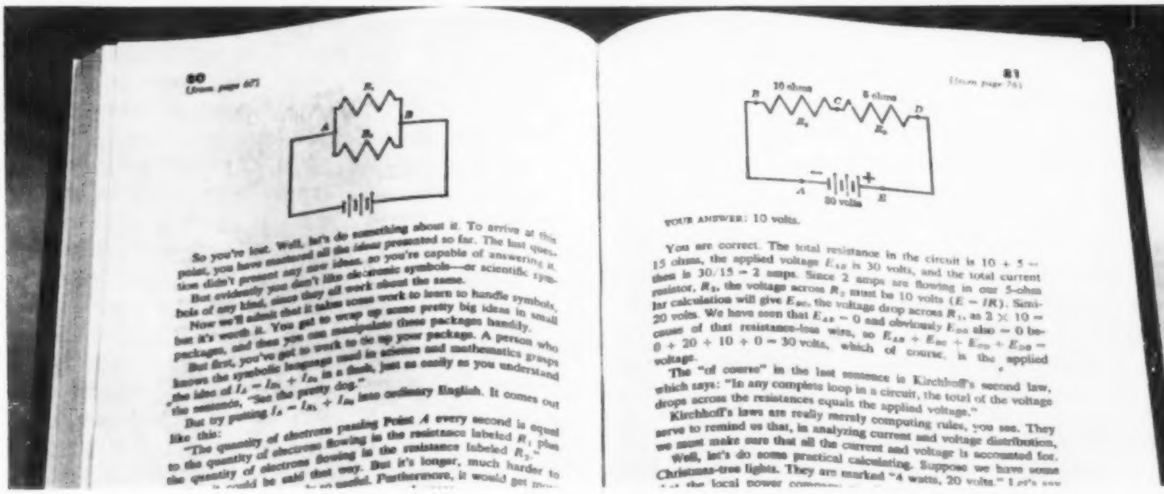
Society has learned to climb above its own rising technology rather than attempt to compete with it. As automatic machines take over routine industrial labor, human laborers must be prepared to control, maintain, and improve upon these complex systems. This means not only massive new training programs, but mass retraining anywhere automation's transition period is briefer than a worker generation.

As a natural answer to this automation-created requirement, the concept of automated education is beginning to emerge. Its initial tangible development, which already has stimulated national discussion, is the controversial "teaching machine."

by **Dr. R. E. Packer,** *senior training systems analyst, General Dynamics Corp.*

As senior training systems analyst for General Dynamics' Electric Boat Division, Dr. R. E. Packer heads research on simulator design and electronics-system trainers for the military. A PhD graduate of the University of Minnesota, Packer has done research on submarine communications. He also has worked as a commercial television director and as a producer for educational TV. His published writing includes fiction short stories as well as articles on developments in mass education.

Photographed by Charles N. Pratt



vances. and a growing population call for increasing amounts of education.

Machines against tedium

Early mechanical teaching aids were simple decks of flash cards with answers on the back, automatic slide and film-strip projectors, instructional tapes, and phonograph records — all barely one step removed from traditional audio-visual classroom equipment. Present automated devices provide for greater flexibility of presentation, more student participation, and additional means to record and evaluate student response.

Future teaching machines promise to be but one part of a complex group of automatic attendance keepers, proficiency testers, report-card printers, and electronic reference librarians — all integrated by

A BOOK BECOMES A MACHINE *when it's designed to choose a student's next lesson automatically, according to how well he has answered the questions on his last assignment, as does the TutorText book shown above (by Doubleday). Below, airmen at Keesler AFB learn basic electronics with the aid of USI's AutoTutor teaching machines, which test students at each step of the course. Test results are used as feedback to determine what material will be presented next, thus permitting students to advance as rapidly as their individual abilities allow.*

central computer control into an efficient automated-education system. Such a system would relieve the human teacher of all the rote drilling and tedious paperwork which should fall below or outside his instructional talents. Full integration of successful automation techniques thus should permit both higher quality and greater volume of educational output per capable instructor.

Future educational facilities must be compatible with a totally new social system; the pace of which is being set by automation. If the facilities are not compatible, the average man and his family cannot be advanced safely ahead of new technology but will be in conflict with it.

The changing mass of education

Mass education has elevated the lower classes to middle classes during the brief period known as modern times. The lower-class void is being filled by the machines. Inventions such as printing, the telephone, movies, and radio-television have pushed the potential ratio of learners-to-teacher successively up to beyond a 100-million-to-one.

Unfortunately, these mass communications media cannot maintain the transmission efficiency of the one-to-one tutor-to-student ratio. They all fail to provide the final essential link from the five human senses to the mind.

In other words, purely presentational media can implement only passive learning. A student may close a textbook, turn off the TV set, or even fall asleep during an educational movie, all with no effect on the presentational pattern. As true teaching machines, these devices are blindly inefficient.

The essential missing concept is feedback—the regulation of a process with a sample of its own output. The new approach of automated teaching utilizes feedback. As information to be learned is presented, feedback from student to device assures the mechanical "teacher" that each part of the lesson is understood, that it has been received by the mind as well as by the senses.

The feedback effect—student response on the one hand, and machine response on the other—is analogous to conventional classroom participation. Positive reinforcement results as the equivalent of teacher commendation, marks, gold stars, or report-cards. Mutual feedback leads to an effective, and close, albeit impersonal, rapport between student and machine, functioning together as a system.

System analysis of education

The system is closed-looped, a characteristic common to all automation processes, and system analysis can be utilized in the design just as it is in the design of automated devices for industrial processing. In the educational process, however, the human occupies a principal rather than a peripheral place in the system. System specifications therefore have been supplied by human-factors engineers and experimental psychologists.

The human learner, in order to "accept" data presented to him, first must have it put forward in many small, clear steps, each logically built upon the concepts in earlier steps. Secondly, the extent of the learner's understanding must be determined and recorded before moving on to a more difficult step. Finally, the learner must be motivated to proceed to that more difficult step.

These human engineering specifications represent the three fundamental concepts of behavioral psychology: stimulus, response, and reinforcement. Implementation of their sequence creates an engineering requirement for display, response, and evaluation-reward components, circuits, or units in any automated instructional system.

A digital computer is almost certain to be the heart of most fully automated educational systems.

Photographed by Joseph Sterling

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2

Similarities between instructing a human student and "instructing" a computer are striking. Computers have been called "essentially stupid" thinkers because they must be told every single thing that they are to do in special, simple terms which they can understand (binary symbols).

This general description also happens to fit the new student. He comes to a subject completely ignorant of its procedures and its definitions. He must be taught its concepts in simple steps and terminology which he can understand.

These parallels have brought about an interchange of terms in describing the two guidance processes. The structure and sequence of "input," or presentation of subject matter, is referred to as the "program" of the course being given on the automated teaching device. And the control code for a particular computer task is referred to as its "instructions."

Straight teaching programs have a single fixed sequence of steps. Branching programs may be altered in both sequence and number of steps by new instructions based on a running evaluation of student performance. Response to either type of program may be by a multiple-choice input selected from among several answers displayed, or by a constructed input written or coded into the device.

A 100-million-people market

Booming public interest in the idea of automated education is apparent from dozens of articles and books which have burst forth in the last two years after the initial report by Dr. B. F. Skinner, of Harvard University.

Sudden popularity of a self-contained device for individual tutoring is not perplexing. The potential market approaches 100-million people in this nation alone. School children, industrial workers, military personnel, adult education groups, and many other segments of a populace that no longer is skeptical of new scientific techniques provide ready customers for a well-designed automated educational device.

Research may force the textbook industry to make room for published automated programs, such as Harcourt-Brace's "English 2600" (for 2,600 program steps). Several other publishers—D. C. Heath, McGraw-Hill, Prentice-Hall, and Doubleday—are following programed-text developments.

Future correspondence courses may be conducted on automatic teaching machines loaned from a correspondence school for the duration of a course. Program cartridges, sent by mail, will make up the lessons.

Public-school study halls may be equipped with individual subject-matter machines that dispense factual content on as many courses as superior students can absorb, while slower students go through the minimum number of required programs. Home tutoring devices may aid students in difficult subjects, or allow them to keep up with their classes during prolonged illness.

Eventually, economical design for magnetic data storage may allow electronic reference units to displace the home-reference encyclopedia, giving students instantaneous audio-visual expositions of any subject in its index.

Teaching machines now available

Most immediate applications of automated instruction devices are for improved military and industrial training. Already, Western Design Div. of U. S. Industries has sold 18 Auto-Tutor devices to Wright Air Development Center. USI's Robodyne Div. has sold 55 of its Digiflex trainers to the U.S. Postoffice for retraining in automated letter-sorter operation.

Hughes Aircraft is using 500 of its own Video-Sonics procedural trainers on its assembly lines.

THE FIVE FACES OF MUTUAL FEEDBACK *between student and automated learning system are represented in this flow sequence. First photo shows the machine display serving as a stimulus, which is responded to in photo number 2; corrected via negative reinforcement (the answer was wrong) in photo 3; answered anew as a conditioned response in photo 4; and accepted by the machine (positive reinforcement) in photo 5. Most so-called teaching machines work in this manner.*

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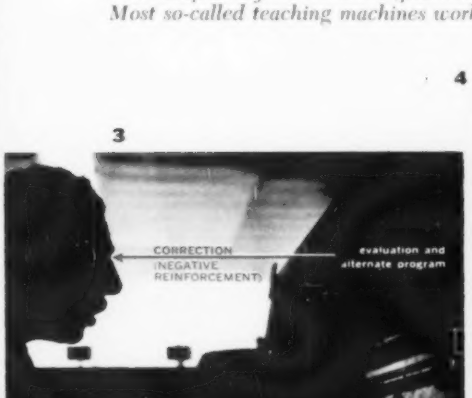

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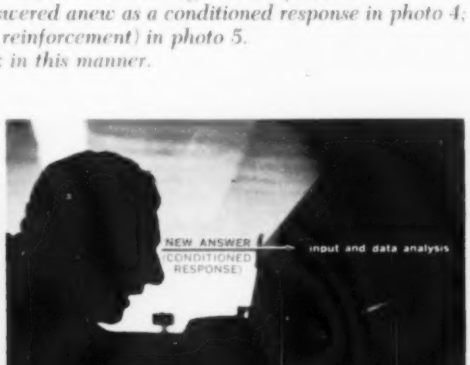

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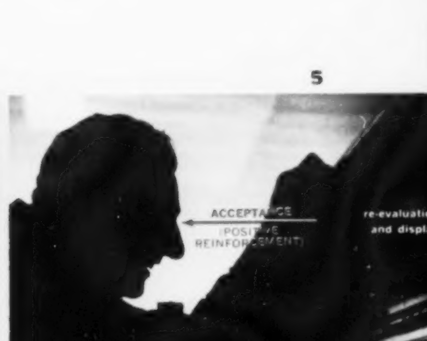


Keesler Air Force Base is evaluating the effectiveness of training in basic electronics, comparing Auto-Tutor's $5,000 prototype microfilm-projecting machines with relatively inexpensive Scramble Books of the same multiple-choice programed content. The Scramble Book, conceived by Norman Crowder (as were the larger USI devices for non-conditioned learning), directs the reading student to differing comments on different pages, according to his choice of answer. Correct response brings the most straight-forward progress through the book.

For the civilian market, the book is being published jointly by USI and Doubleday under the "TutorText" title. The first program, an "automatic bridge tutor" publication, was released in November, 1960. Advertised as being comparable to private tutoring from Charles H. Goren, whose method is used, it carries a learning guarantee. Doubleday "TutorTexts" also are being published in electronics, binary arithmetic, and algebra.

Eugene Galanter of the University of Pennsylvania has developed a similar multiple-choice programing method which is used in a small mechanical Tutor by General Atronics Corp. of Philadelphia. A companion machine, the Class Monitor, tells an instructor, whether all members of his class are following each point in his lesson. The Navy is using these devices experimentally.

Skinner's trained pigeons

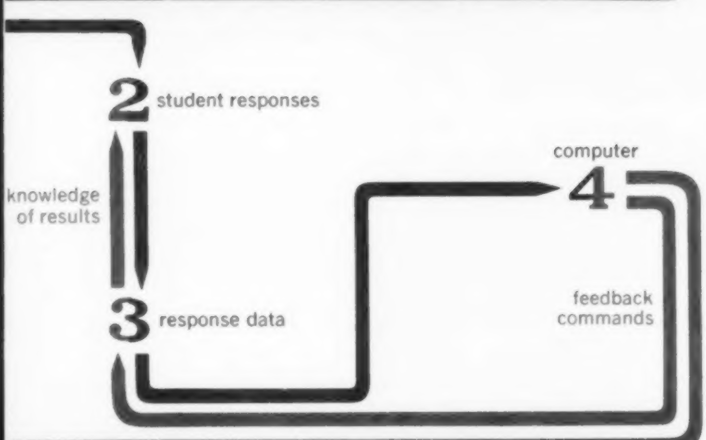
Constructed response is the theoretical opponent of multiple-choice methods because it insists upon unaided recall of the correct answer. This basis for automated-teacher design was developed (mostly by Skinner) along purely behaviorist lines of conditioned response. Skinner tested it through a remarkably efficient training program of pigeons! It now has been implemented for human learning by Rheem Califone, Southgate, Calif., in the Didak, a machine which provides for a write-in response and self-evaluation.

Developmental designs for automatic-teaching hardware are varied. The Rheem device is typical of the small mechanical machines which use the basic Skinner write-in technique. It is typewriter-sized and shaped, and has a small window which displays the question and a second window where the answer is to be written.

The student's answer is covered mechanically to guard against erasure when the control lever is advanced to reveal the correct answer. By pressing a "correct" button, the student eliminates the question from the next cycle. If he was wrong, he writes the correction in beside his original answer on the program tape. First models of this device sell for $157.50

Hamilton Research Associates is about to market a similar device, the Visitutor, which will project the stimulus on a small screen. An Auditutor will

JOHNNY'S ANSWER *to a test question, if correct, will turn the page to the next lesson of the textbook inside General Atronic's mechanical Tutor, shown in use at left. On machine pictured above — smallest of USI's AutoTutor line—push-button answers to multiple-choice test questions starts feedback system for selection of student's next program. Below, a Bendix G-15 computer provides the basis for the experimental system outlined in the diagram and designed by System Development Corp. for public school use. Conventional classroom instruction is combined with individual "attention" from the machine, which has ultraflexible feedback. In selecting a lesson for a student, the computer is responsive to his score and his timing.*



be available for synchronous operation in language instruction.

Western Design's AutoTutor is console size. It contains a microfilm-reel projector and a selection circuit controlled by a student-operated multiple-choice panel of buttons. Its facility for searching through a several-thousand-step sequence for branch-response displays makes it expensive. First units are $5,000.

Training by conditioned reflex

The Digiflex operator-trainer being used by the Postoffice Dept. for letter-sorter trainees guides them toward the correct response by pure conditioned reflex rather than cues in the subject content of the questions, as in the verbally programed trainers.

Installed in a desktop, the Digiflex keyboard is synchronized with a visual presentation to the entire group. Correct-response buttons are raised automatically under the hand of the postal clerk, so that his fingers push them down again by simple reflex action, and he gradually learns the pattern.

Research in automated teaching is being carried forward at several universities, principally in construction and testing of programs for introductory courses now being taught in oversized lecture classes to all incoming freshmen. Hamilton College, Clinton, N.Y., has a $204,000 grant from the Fund for the Advancement of Education, Ford Foundation, for a three-year development of programs in logic, languages, psychology, and mathematics. An associated private corporation is offering authors of successful programs royalties similar to those awarded authors of plays.

Rheem is designing a complete engineering course program for the University of California at Los Angeles. Also, UCLA and the San Jose public school system are conducting a joint experimental course under the direction of Dr. Sidney J. Pressey, who first broached the idea of automated instruction in the 1920s.

Mechanized language instruction

The New York Institute of Technology is one of several universities with completely mechanized language-instruction booths, equipped with earphones, microphones, television, and feedback-controlled tape recorders.

Rensselaer Polytechnic Institute scientists are designing an advanced educational device with electronically stored program and flexowriter typing of both questions and student responses. Several small research corporations, some formed specifically for automated-teaching research, are emphasizing various aspects of its development.

Applied Communications Systems of Culver City, Calif., has an audio-visual presentation device which provides for "build-up" production of small

numbers of items by one person, rather than full assembly-line production involving a new worker for each assembly step.

Robert E. Corrigan Associates of Garden Grove, Calif. is recording IBM-card response from students watching TV medical classes via a Teletesting device.

Teaching Machines Inc. of Albuquerque, N. M., already has produced and statistically evaluated programs in algebra and several languages.

Computer Control Co. has produced a SPEC (Stored Program Educational Computer) to train digital-computer designers and technicians.

Smith Harrison of Devon, Pa. has a math-teaching device with a dial for numerical response.

Williams Research Corp. has placed film, sound, and punch-tape response units in a "teaching desk."

Itek, of Boston, and many other research groups actively are investigating programed instructor techniques.

Dr. Ramo's Intellectronics Division

Many larger corporations are taking definite steps to get into the automated-education industry. The Intellectronics Div. of Thompson Ramo Wooldridge is doing active teaching-machine research as a pet project of Dr. Simon Ramo. Bell Telephone Laboratories, IT&T, Motorola, Minneapolis-Honeywell, Bendix, Varian Associates, Royal McBee, and Philco all are known to be seriously at work on advanced designs for electronic teaching systems.

Two of the big encyclopedia companies, choosing to join (rather than beat) the new individual-educational packets, have announced automatic tutor plans of their own. The Book of Knowledge has a low-cost written-response machine and Encyclopedia Britannica's Film Div. will distribute simple loose-leaf notebook "machines" with lift-up-tab answers to high school and college math and language classes.

These programs, now being tested in Roanoke, Va. and in other schools across the nation, were developed by Dr. John E. Everett, first chancellor of New York City Municipal Colleges, while he was president of Hollins College. The automatic courses will be available this fall for about $10 a student. New plans for research and devices for automatic education are being announced almost daily.

System Development's broad assault

Possibly the broadest assault on the potentialities of automated education has been generated by the non-profit System Development Corp. of Santa Monica, Calif. This firm, the primary mission of which is the design of the SAGE system's computer and personnel-training programs, is organizing an active automated-teaching facility equipped with a Philco 2000 computer.

System Development's early electronic teaching system makes use of a Bendix G-15 computer with stored programs on five alternate levels of difficulty. If a student's percentage of incorrect responses begins to climb too high on one level of program, the device automatically branches to an easier sequence until the required proficiency allows automatic switching back to the more difficult stimuli.

This non-sequential program can be centrally controlled from one computer for up to 20 student keyboards and projected displays, thus providing automatic group instruction. The random-access 35-mm slide projector provides 600 multiple-choice displays, and is being patented as a basic feature of the system.

System Development also is designing automatic attendance, assignment, and grading units, anticipating the day when a school's routine paperwork may be processed completely by a central digital computer. The corporation has a proposal before the Navy Office of Scientific Research for group-teaching experiments, and another proposal before the National Education Assn. and the American Psychological Assn. for formation of an automatic-teaching standards committee.

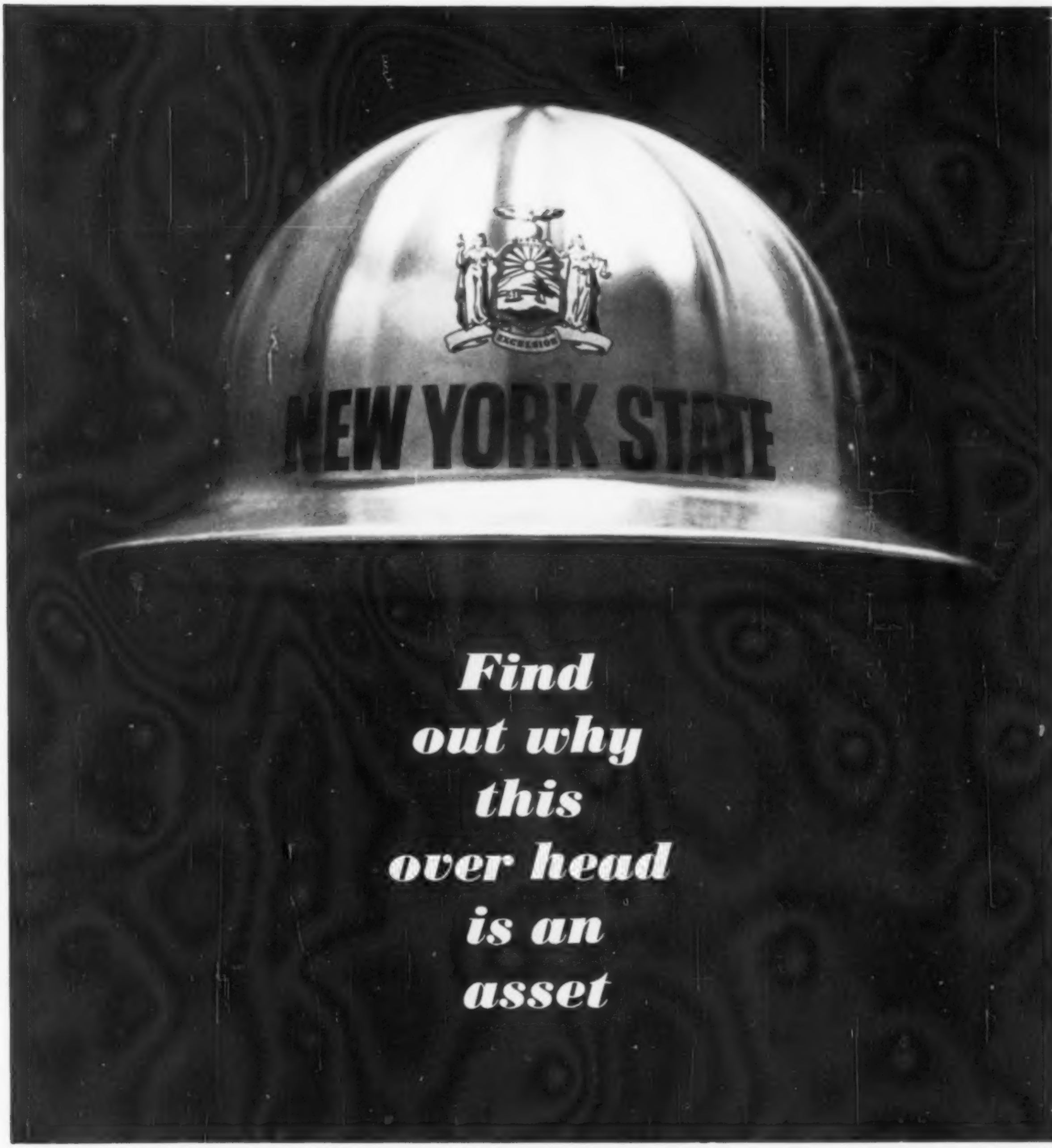
Aside from the much-discussed and unwarranted fears of teachers (who see themselves displaced by machines) and the natural reluctance of administrators to embrace the impersonality of automation, the greatest obstacle to its educational application is the lack of any experience to guide the design of either programs or devices.

Main principle: short bursts of learning

There is agreement on the main principle: *the learning must be presented in short bursts of information, each eliciting a student response that is immediately reinforced by the machine.* The exact style and detail of presentation of each subject now must be constructed and tested pragmatically until some logical design or formula approach is proved.

Whether the "recall" of a constructed response produces deeper learning than the "recognition" of a multiple-choice response is not established. Whether the negative reinforcement of a great number of incorrect choices introduces the danger of remembering wrong answers also is unknown. And whether a flexible, reliable automatic input-output relation between student and machine can be implemented fully is yet to be seen.

Finally, the philosophical line between factual instruction and dogmatic indoctrination must be drawn clearly if automated-educational systems are to further individual creative development rather than rote unimaginative conformity. Whatever the ultimate form of the automated-education industry, it is virtually certain that development—from what is now little more than a series of conceptual ideas to what surely will become a wide variety of useful applications—will be accelerated by increasing demands for efficient education. ■



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GET UP TO DATE ON NEW YORK STATE...WHERE THEY'RE TALKING THE BUSINESSMAN'S LANGUAGE

by **Dr. Rolf W. Peter,** *manager, electron devices division, Watkins-Johnson Co.*

New Materials for Electronics

INCREASING man's control over nature has enabled us to communicate better, travel faster, and produce more goods and services per man hour. In large part, this technical progress is the result of man's learning to build more intelligence into machines so they can perform more useful functions.

Many branches of industry are involved in developing machine intelligence (through mechanization and automation) and in increasing production. Of all industries, however, electronics seems to have the most potential for future technological development.

Thus, it is not surprising that electronics is today's fastest growing major industry. Fiftieth in rank before World War II, electronics now is in fifth place among broad U. S. industry classifications. More and more industries and businesses are adding electronics laboratories and divisions to their engineering activities and product lines. Some industries, such as airframe manufacturers, are competing with established electronics firms. More conservative industries, such as steel and food producers, are looking to electronics as a fast way to progress.

Controlling the molecule

In this unparalleled, explosive, electronics expansion of the last two decades, the spotlight has been turned on materials, or solid-state, research. Materials research has reached this prominent position because man's key to nature's unlimited resources rests in his ability to control matter on the atomic and molecular scale.

The importance of atomic control can be appreciated in the impressive development of nuclear power generation; tiny, transistorized radios; and color television, made possible because blue-, green-, and red-emitting phosphors have been synthesized. (A phosphor is made up of microcrystals of a basically insulating compound, such as zinc sulfide, to which is added less than 1% of luminescent activators, such as manganese.)

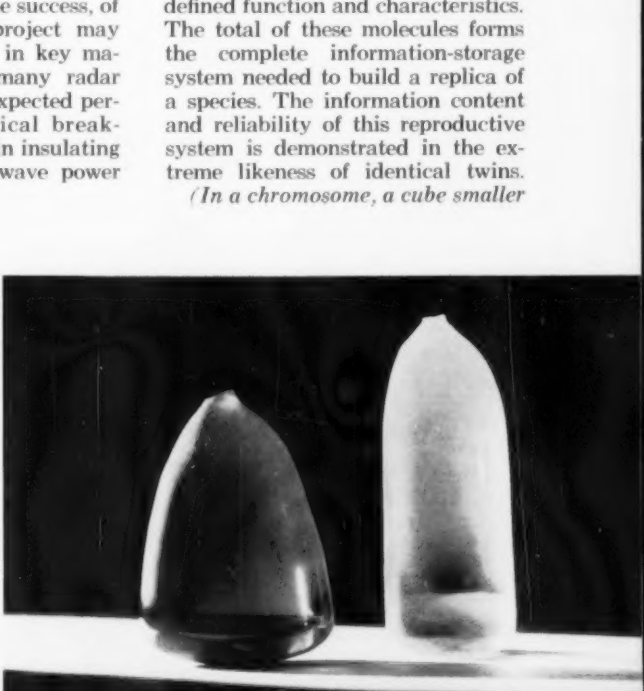
The progress, often the success, of an entire engineering project may depend upon advances in key materials. For example, many radar systems did not reach expected performance until electrical breakdowns were eliminated in insulating materials in the microwave power tube.

Discovery of new materials often makes existing designs obsolete, as happened in the receiving-tube field when the transistor appeared. Breakthroughs of this nature, though rare, contribute greatly to the position of materials research as a powerful factor in electronics progress.

Molecular building blocks

The ultimate goal of materials research is characterized most vividly by the now-familiar term, "molecular engineering"—use of molecules as building blocks in forming materials, allowing all functions of a system to be designed into a minimum volume of matter.

Nature has achieved this goal in many parts of living organisms. For example, the chromosome, blueprint for reproduction of living species, is "molecularly engineered." Every molecule (or gene) in a chromosome has its distinct and well-defined function and characteristics. The total of these molecules forms the complete information-storage system needed to build a replica of a species. The information content and reliability of this reproductive system is demonstrated in the extreme likeness of identical twins. *(In a chromosome, a cube smaller*



MAN-MADE CRYSTALS *of rutile (titanium oxide) and ruby (aluminum oxide with a trace of chromium), were formed by Verneuil method. Basic material in powder form is fed into flame zone, where combustible gas is used to create temperatures as high as 3000 C. Powder melts and falls on seed crystal, which is withdrawn gradually as the new synthetic crystal grows.*

than 100 atoms on a side stores at least one "bit" of information—a yes or no indication. This storage density is at least 1,000 times greater than that achieved in photographic or thermoplastic memory systems. These advanced systems in turn contain about two orders of magnitude more information per square centimeter than the best present magnetic-tape storage, where the maximum achieved is about 1-million bits per square centimeter.)

Progress in electronic-component miniaturization in recent decades is shown in the flow chart below. Even the most advanced laboratory achievements in integrated electronics still are many orders of magnitude behind the human brain in the number of elements per cubic foot. It is important to keep the goal of materials research clearly in mind, as it points up the long distance left to travel from even the most advanced materials research of today, to the ultimate molecular-engineered material, component, and integrated system of the future.

At present, we know how to control *bulk* properties of materials on a molecular scale. For example, we can grow almost perfect crystals, then add various "activators" in small amounts. But we have not yet learned to control the *surfaces* of such bulk materials to the same degree, nor do we know how to grow thin single-crystal *films* of these materials in similar structural purity.

To understand the current status of materials research in electronics we should look at the materials researchers themselves. The work is performed mostly by teams of physicists, inorganic chemists, metallurgists, and ceramists. Organic chemists slowly are becoming part of the materials research scene in some electronics laboratories. Biologists and physiologists still recognizable as such are a definite rarity. More biologists and organic chemists must become active in electronics-materials research if the molecular-engineering goal is to be achieved. But materials scientists have come a long way and rightfully can be enthusiastic about progress to date.

The task of a materials scientist when asked to provide an improved material can be extremely complex. Consider the plight of the scientist asked to come up with a material having higher carrier mobility at elevated temperatures as a basis for improved heat-resistant semiconductor devices.

4,000-plus combinations

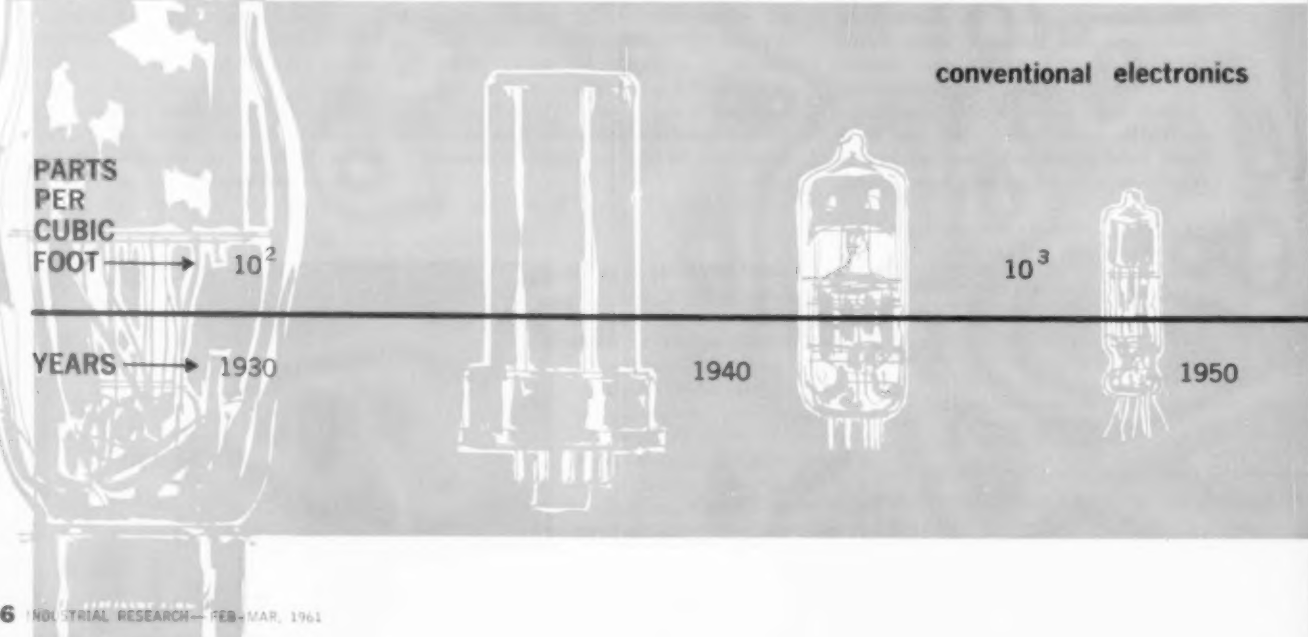
The first step for the materials scientist (be he chemist, metallurgist, ceramist, or physicist by profession) is selection of a material that might provide the best combination of characteristics. He has the whole periodic table of elements at his disposal. Combining two elements at a time will give him more than 4,000 combinations, the majority of which are mixtures and the minority, actual compounds. If he also considers compounds built up from three elements, the number of materials awaiting his investigation exceeds 100,000. The task in its full aspect is obviously fantastic. Besides some general rules and chemical handbooks, he needs good horse sense and infinite patience.

One day, a fast computing machine will supply physical data on a large number of simple compounds. The machine then will select the one or the few best-suited materials: for example, gallium arsenide as the preferred binary semiconductor in our example (as shown on the table of semiconductor characteristics on page 57). An ambitious theoretical study to set up such a computer program is underway at RCA Laboratories.

However, there will be years of transition from theory to reality. Until then the materials scientist, in his first task of selection and combination, will have to rely on past experience and his horse sense—and patience.

Even when such a computer is available, two other demanding tasks remain: the ultimate purification of the chosen material, and its controlled alloying, "doping," and activating.

PROGRESS IN MINIATURIZATION *of electronic components, from the vacuum tube of the '30s to the tiny solid-state devices of today, charts a continuous course toward what many scientists see as the ultimate goal – materials with the packing density of the human brain, which still is many orders of magnitude ahead of even the most advanced laboratory achievements in integrated electronics.*



Semiconductor Characteristics of Ge, Si, InP, and GaAs

SEMI-CONDUCTOR	MELTING POINT, °C	BAND GAP, ev	ELECTRON MOBILITY, $cm^2v^{-1}sec^{-1}$	HOLE MOBILITY, $cm^2v^{-1}sec^{-1}$	DIELECTRIC CONSTANT	POTENTIAL TEMPERATURE RANGE*, °C
Ge	936	0.7	3900	1900	16	−200 to 100
Si	1420	1.10	1500	500	12	−50 to 300
InP	1070	1.25	6000	160	10.9	−200 to 400
GaAs	1240	1.40	12,000	450	11.1	−200 to 475

*The temperature limits are estimated from impurity activation energy, band gap, and conductivity measurements.

Cook-detective-artist

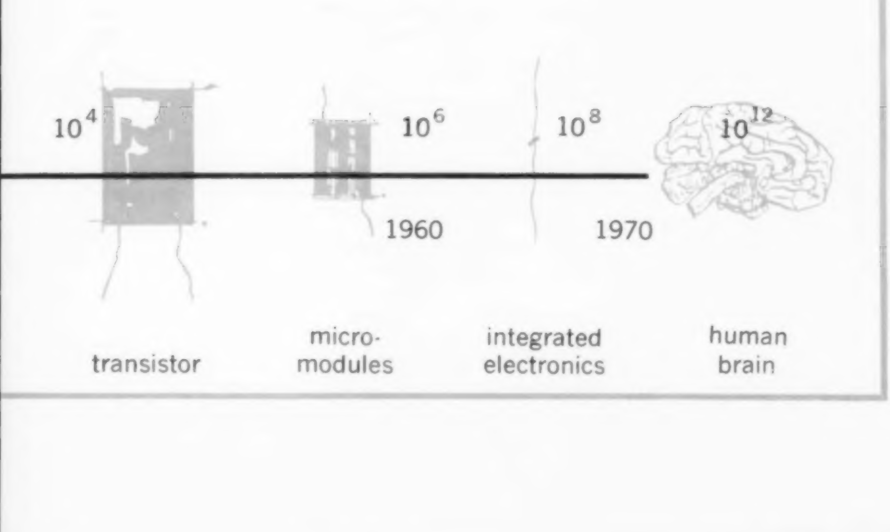
The attitude and talents of the scientist involved in purification have to be similar to those of a Sherlock Holmes. The "killers" he's after are unwanted impurities and defects in the materials. In the example of gallium arsenide, these defects appear to be as tough and elusive as the criminals in a perfect murder!

The third job in materials synthesis is one for an artist. The artist-scientist must be highly sensitive to the changes he brings about as he alloys the purified elements and compounds and finally introduces active impurities to create the desired quality or phenomenon. Germanium or gallium arsenide, for example, may be activated to become basic material for a transistor or, using different formulas, a tunnel diode, or an infrared-photosensitive detector.

The scientist engaged in materials synthesis thus must wear three hats: he must be a cook with horse sense, vast experience, and good recipes; a detective with imagination and analyzing power; and an artist with sensitivity.

Although controlled materials synthesis is the ultimate objective of molecular engineering, it is only part of an integrated materials-research activity. If real progress toward the ultimate goal of materials research is expected, the synthesis approach must join hands with the measurements and the theoretical approaches.

Success of the measurements man



(usually an experimental physicist, physical chemist, or physical metallurgist) depends upon his cleverness in asking the right questions in his experiments and upon having equipment sensitive enough to hear nature's answer through the background noise.

The theorist (usually a theoretical physicist or applied mathematician) tries to find a theoretical model to explain as many of the measured results and curves as possible. To check his model, he advises the synthesis man on what materials to make and the measurements man on what crucial experiments to conduct on these materials.

In all three approaches, materials scientists depend upon advanced equipment, and often these scientists can be no better than their equipment. Materials synthesis is based upon spec-pure chemical laboratories; facilities for high-temperature synthesis such as image-arc, flame-fusion, arc-melt, electron-bombardment, and induction furnaces; and high-pressure facilities for such processes as hydrothermal synthesis.

Similarly, modern equipment must be available for highly technical measurements. Examples are magnets with very uniform fields over large areas, spin and nuclear magnetic resonance apparatus, sensitive susceptibility-measuring equipment, and spectrometers for all spectral ranges, from radio and microwave to optical light, electron, and neutron spectrometers.

Finally, the theoretical approach depends upon pencil and computing facilities, principally high-speed digital computers, and occasionally analog equipment, including the electrolytic tank. In contrast with the other two approaches, failure in the theoretical approach usually can not be blamed on the equipment!

The scientist is rare who is able to work effectively on all three approaches of materials research. Therefore, materials research is carried out most successfully by teams of scientists of different professions and talents who *together* cover the three approaches of synthesis, measurement, and theory.

Knowledge and conductivity

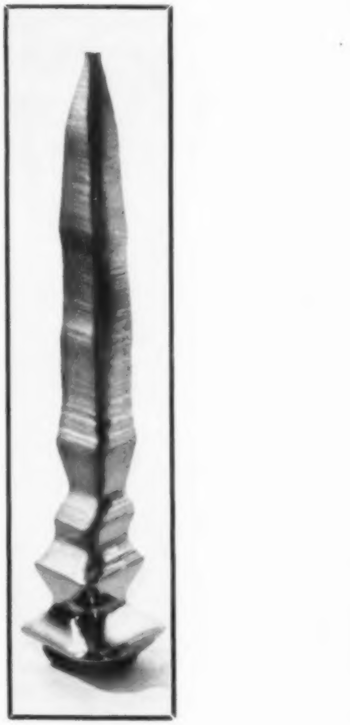
The enormous variety of materials studied at an electronics-research laboratory can be classified in many different ways. In the table at right, classification is according to the energy band-gap (level of electron energy and momentum) of the material. As indicated, this order is inversely related to its conductivity.

GALLIUM ARSENIDE *synthetic crystals, above and at right, were formed by the Czochralski method. Inside a sealed quartz tube, a seed crystal — guided from the outside by a magnet — is dipped into a melt of the basic material. The seed then is slowly rotated and retracted. One of the oldest methods for growing crystals, the process produces synthetics of high quality. Each of the three crystals shown on these pages is approximately 10 centimeters long.*

The conductivity scale also seems to give an approximate indication of the degree of existing physical knowledge on any of these materials and related phenomena—an astonishing fact since some of the earliest-known and most extensively studied materials head the list (such as insulating and luminescent materials, followed by photoconductors).

ENERGY BAND-GAP	CONDUCTIVITY (IN DARKNESS)	MATERIALS	
high	negligible	dielectrics (insulators)	ferroelectrics
		phosphors	
		photoconductors (visible)	
	low	paramagnetic materials	ferrites
		emitters	
		photoconductors (infrared)	
		semiconductors	
low		thermoelectrics	
zero	high	metals	metallic ferromagnetics
zero	infinite	superconductors	

Dr. Rolf Peter recently became manager of Watkins-Johnson Co.'s electron devices div. after nearly 13 years with RCA, where he was director of the physical and chemical research laboratory. Holder of some 20 U.S. patents in the electronics field, Peter is a PhD graduate of the Swiss Federal Institute of Technology.



Although scientific studies on luminescence go back to the 16th century, the basic complex mechanisms involved still are much less well understood than semiconductivity, a relatively recent addition to the list of observed materials phenomena.

Reason for this peculiar situation lies in nature itself. Every additional electron volt (ev) of the energy gap increases (by at least an order of magnitude) the difficulty in synthesizing a crystal of equal chemical and structural purity. Further, similar imperfections usually produce more profound changes in the electrical properties of high-band-gap materials than of low-band-gap materials.

This phenomenon may be related to the fact that the atoms in a higher-band-gap crystal generally are held together by stronger binding forces. Consequently, any imperfections might be expected to create greater changes.

Semiconductors are distributed near a 1-ev gap, visible photoconductors around 2 ev, and phosphors around 3 ev, and their order of complexity is known to increase accordingly. In addition, the synthesis chemist's or metallurgist's difficulties grow when he progresses from elemental crystals such as germanium or selenium, to binary compounds such as indium phosphide or cadmium selenide, or to ternary compounds such as silver iron telluride.

Theory of purity

Solid-state theory currently can explain only the phenomena found in highest purity column-IV crystals, germanium and silicon. (This standard of purity requires that the foreign atom content be less than one in a billion atoms.) Progress toward better understanding of materials, therefore, is linked closely to the availability of chemically and structurally purer materials.

Even though our basic understanding of many materials remains elusive, a few striking recent advances will illustrate the extent to which materials can be expected to affect various areas of electronics in the near future.

Major improvements have been achieved in photoconductors—materials which become conducting upon illumination by light. Photoconductors (for example, lead sulfide and cadmium sulfide) are the basic materials for photo-detectors and television-pickup devices.

During the last year, crystals were synthesized with about two orders of magnitude higher performance factors than ever known before, as shown in the chart on page 60. Eventually the same performance may be achieved in powders and sintered layers which are required for most photoelectronic devices.

Infrared - sensitive photoconductors have been perfected to a similar degree during the last few years. Their spectral response now can be tailor-made to an amazing degree.

The solid-state triode

The phenomenon of space-charge-current flow, well known in vacuum tubes, recently was measured in highly purified insulators such as cadmium sulfide. Initially considered no more than a particular aspect of photoconduction, space-charge-current flow now has been used in a solid-state analog to the vacuum-tube triode. Although still very much in its infancy, this high-input-impedance amplifier device may herald a new class of insulator devices, important as solid-state compliments to the low-impedance semiconductor devices.

In all communications systems, signal amplification remains the pre-eminent function. Semiconductors today provide the basis for the most important solid-state amplifier devices for any frequency from audio up to microwaves. After an extensive search, gallium arsenide was selected as the semiconductor material with the best combination of advantages.

(As is evident from the table on page 57, the performance of gallium arsenide at relatively high temperatures is comparable to that of germanium at room temperature.) Much effort is being aimed at the purification and controlled "doping" (addition of impurities) of gallium arsenide in several laboratories.

"Somehow, I pictured Earth people as looking quite different."

In 1958, the first operating gallium-arsenide transistor was demonstrated, a major event in this field. Also, gallium-arsenide parametric and tunnel diodes have a higher frequency response and lower noise factor than any similar device made of germanium or silicon.

The last word on semiconductor materials has not been spoken yet, of course. The search for better three-element compounds has led to two materials with very promising properties for tunnel diode and thermoelectric applications. Still better ones may be uncovered.

Information in a speck

Information storage for video recording and digital computers is being achieved in ever-tinier specks of ferromagnetic and other materials. From magnetic cores—printed ferrite and metal places with microscopic holes—the need for higher information-storage density leads to

magnetic tapes and films. Further improvements in ferroelectrics may make them practical for certain switching and storage functions. Basic studies carried out on new superconductors and on the mechanism of switching will permit new designs of cryogenic memory and storage devices.

Materials research also is of prime importance for electronic power generation. Electronic conversion of radiation into electricity, with no moving parts, opens many new possibilities. Photovoltaic, thermionic, and thermo-electric principles are most promising and are mutually complementary in their operating temperature ranges and fields of application. All three methods depend critically upon new materials for success.

The best silicon photovoltaic cells, such as are used for secondary power supplies in satellites, now convert about 10% of the available solar energy. Research is directed toward increasing this efficiency even further with better materials.

Novel refractory metals—for example, transition metal carbides—are being developed to improve the critical part of thermionic converter tubes, the high-temperature emitter. Energy conversion efficiency of about 10% has been reported for operations at a cathode temperature of about 2600 C and an anode temperature of more than 1000 C. Materials advances can be expected to improve this efficiency.

Efficient thermo-elements

Thermocouples, complementing thermionic converters, are best suited to operate at temperatures below 1000 C. Recent thermoelectric-materials research has led to new, very promising semiconductor alloys.

With thermo-elements operating at a temperature drop of from 300 C to room temperature, energy-conversion efficiencies as high as 7% have been measured. But materials developed for the range up to 1000 C promise to more than double this efficiency. Although they are still less efficient than mechanical heat engines, thermionic and thermoelectric power converters already have proved valuable for special applications and, depending entirely upon advances in materials, eventually may become a major factor not only in secondary, but also in primary energy generation.

Materials for thermoelectric cooling below room temperature are quite different in composition from those designed for power generation. The temperature range of operation is one of the main factors determining materials composition.

Advances made during the last decade may be gaged by considering the material's "figure-of-merit." At RCA Laboratories, for instance, the figure-of-merit (or index of quality) was about 0.0003 in 1951, and in 1961 is more than 0.0035, an increase in merit of about 12 times in 10 years.

In practical terms, consider that the cooling efficiency of a thermoelectric refrigerator based upon these new materials is about equal to that of a small conventional refrigerator. Considerable materials improvements beyond this achievement are theoretically possible and highly probable.

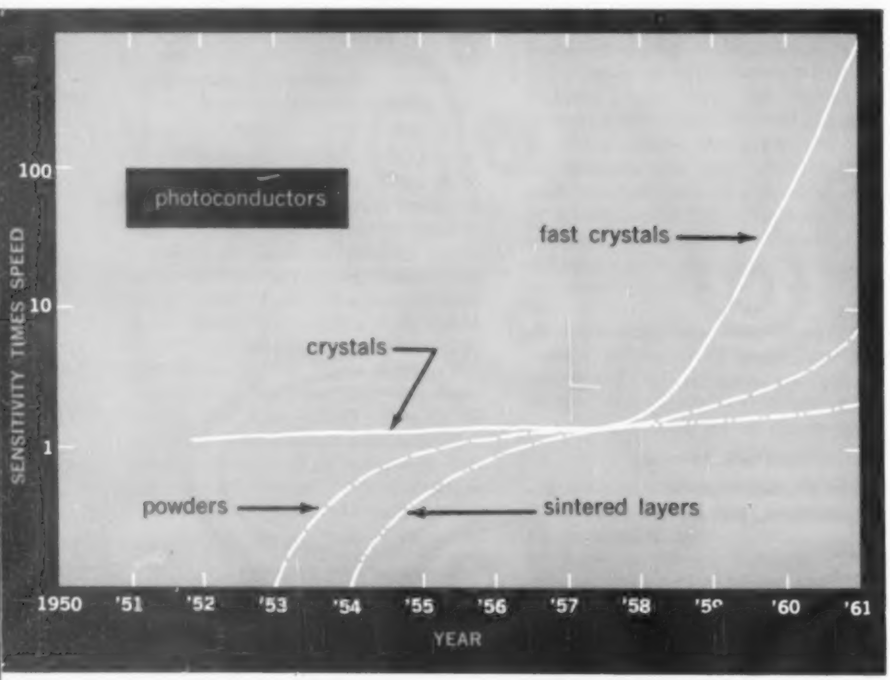
Heterogeneous materials

While up to now the principal materials-research efforts have been aimed at producing structurally and chemically pure crystalline materials with uniform properties, it can be foreseen that materials studies will expand into the field of heterogeneous materials and materials with controlled nonuniform properties.

Examples include improved thermoelectrics with "tapered" properties (changing from the hot to the cool terminal, optimized at every point along the way); silicon whiskers with very high tensile strength embedded in a ductile matrix such as molybdenum or aluminum, resulting in a heterogeneous material of greatly improved mechanical properties; micro-honeycomb and laminated materials; and atomically layered materials with very nonisotropic properties.

In the future the main research attention gradually will shift from crystalline bulk-materials studies to thin layers and films, and to the surface and interface problems connected with such films. These fields of materials research still are virtually unexplored, and can be expected to yield many great advances.

True molecular engineering, the ultimate goal of materials research, remains far in the future. Much more knowledge has to be accumulated on the basic properties of matter to make possible any extensive engineering on the molecular level. But long-range fundamental investigations, many of which now are underway, can be expected to produce the new insight needed to provide broad scientific guidance in today's accelerated search for improved materials. ▪



PHOTOCONDUCTOR IMPROVEMENTS *have been dramatic during the last year. Crystals are being synthesized with performance factors about two orders of magnitude higher than formerly achieved. Work now is underway to bring about similar improvements in powders and sintered layers.*

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(continued from page 22)

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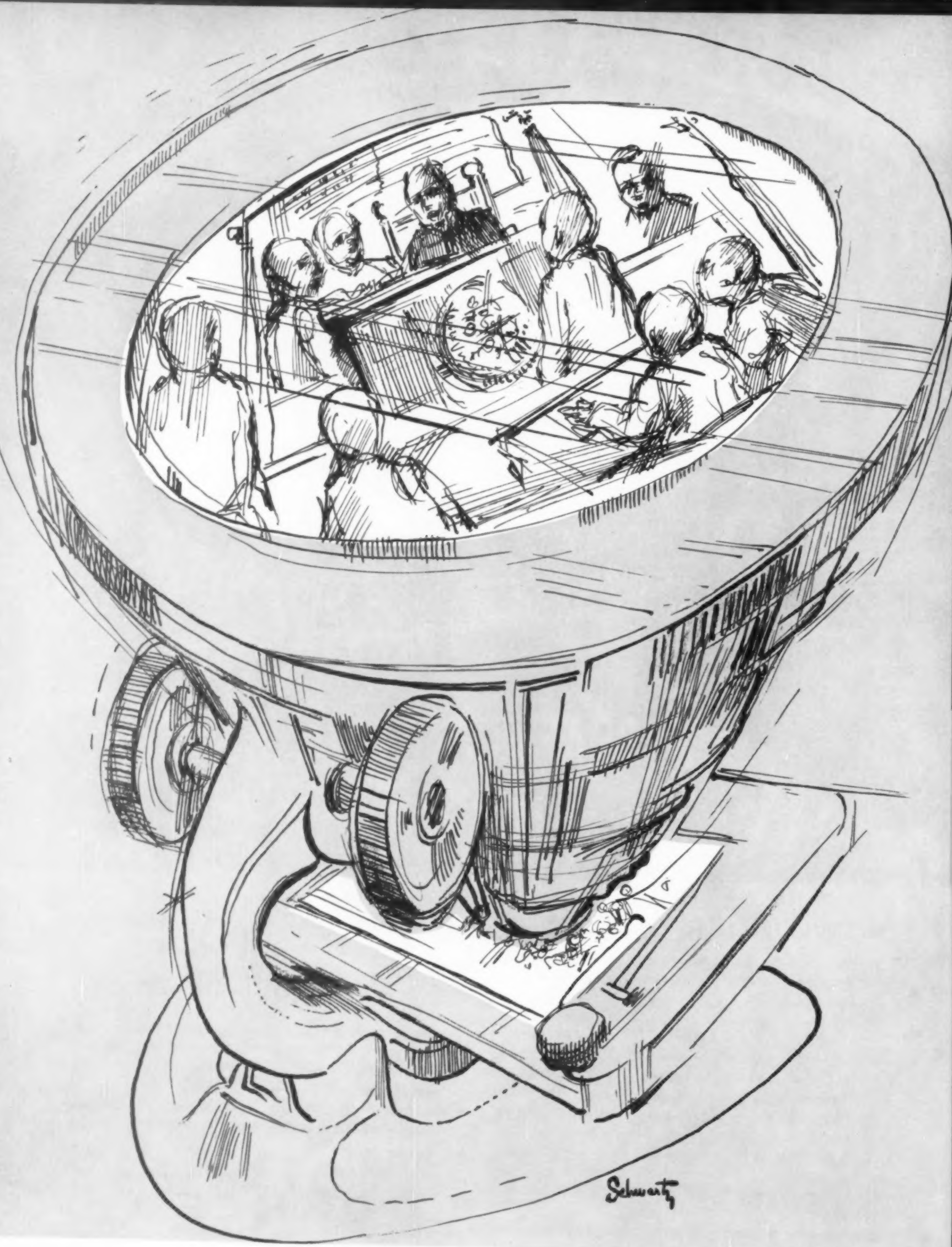
Schwartz

by **Leonard M. Taussig,** *director, Taussig Associates*

Scientific Sleuthing with a Metallurgist

One of the most challenging and unique phases of engineering and science is the investigation of structural and material failures as connected with litigation. This type of investigation demands use of modern test equipment and intimate knowledge of test methods, all tempered by the practical aspects of legal science. Investigations must be carried out on a highly technical level, but the results must be put into non-technical language. Undoubtedly, the greatest difficulty in science-legal matters is the inability to interpret technical facts into words that the insurance adjuster, lawyer, and jury can comprehend easily.

Because of the author's background, all of the examples and case histories in this article are from the metallurgical field; yet the sleuthing process should be of interest to all technical men, whether at the research, testing, or management level. The need for company executives and engineers to understand how a competent investigation is performed becomes evident when a situation involving their products or employes is brought for legal action.

If the facts point to negligence on the part of the company, the company can work towards a quick settlement without unnecessary litigation. If the facts show no general negligence on the part of the company, the company then can aim towards relief from liability. It must be emphasized that the pendulum can swing both ways, and either way can lead to a firm's eventual benefit.

The field of scientific investigation is broad. Sleuthing metal failures, for instance, requires knowledge of metallurgy, chemistry, spectrography, design, and many other sciences. Before delving into some actual case histories, it might be best to acquaint the reader with techniques commonly used in failure investigations.

Testing without destroying

The formation of a metal fracture can tell a tremendous story to the trained investigator. The presence of fatigue conditions, impact failures, cracking from inherent defects, and other types of fractures can be determined from visual observation and recorded photographically.

Other nondestructive tests are designed to detect flaws that can't be seen, for instance, by using x-rays. X-ray examination is performed in the same manner as in medical diagnosis, but with higher voltage equipment.

A variety of nondestructive test methods are available, such as:

- *Magnetic particle inspection* (locating near-the-surface, but invisible, defects by the controlled magnetization of ferrous metals).
- *Sonic inspection* (finding defects by reflecting ultrasonic waves from defective areas).
- *Penetrant inspection* (penetrating surface defects by a flourescent or dye penetrant, and viewing by ultraviolet light).
- *Eddycurrent inspection* (employing eddycurrents to test characteristics such as electrical conductivity, magnetic permeability, and the modulus of elasticity).

The chemistry of a metal

A test required in almost all failure investigations is chemical analysis of the metal elements, since the chemistry of a metal can play an important part in its properties and actions. One method, spectrographic analysis, is performed by firing a specimen with an electric arc and photographing the spectrum of the vapor that is given off.

This analysis is specific for 72 of the 100 elements. It records these elements simultaneously so that, when required, very minute samples can be used. Commonly used by all types of industry for the analysis of metals, alloys, and ores, spectrographic analysis is employed by police laboratories to identify such items as paint samples found on the clothing of hit-and-run victims.

It can be used to identify poisons and even chemical elements in grass, as evidenced by a recent assault case in New York state. (The suspect had grass on his trouser cuffs, and the spectrograph proved that the grass could only have come from the place of the assault.) The spectrograph

Leonard M. Taussig, an Industrial Research technical consultant, is director of Taussig Associates, a metallurgical consulting firm which he organized in 1954. He formerly was chief metallurgist for Magnaflux Corp., with which he still is associated as a consultant. Taussig holds a BS in metallurgical engineering from Illinois Institute of Technology, where he also has served as a faculty member.

also has been used to identify wires used in bombings to establish their origin and place of purchase.

Another analytical method, wet chemical analysis, is applied to those elements that do not respond to spectrographic analysis. This type of analysis requires dissolving metals in acids or other liquids and analyzing the metal content via standard precipitation, titration, color detecting, or combustion methods.

'Fingerprints' in metal

Metallographic examination is to a metallurgist as finger-printing is to an FBI agent. A metallograph is a special microscope for viewing the structures of metal and photographing them. Almost the complete history of fabrication, forming, and treating of a metal can be determined from a metallographic examination. If a defect can be observed, its origin and nature usually can be pinpointed.

Whenever possible, our scientific sleuth prefers to supplement his investigation with actual physical, destructive tests of the part in question. In most cases, a court order or written agreement is required, and in the author's experience cases have been lost because both sides had not agreed upon destructive tests.

A disadvantage is that these tests require a large portion of the failed part for accurate results; therefore, unless the examination is made on a large part such as a truck axle, physical tests usually are impossible.

Measuring hardness of a metal is an important physical test conducted by applying a known load on the metal through a diamond point or a small ball. The depth and geometry of the indentation becomes a relative measure of the metal's hardness.

Stress analysis

Probably the most complicated of methods available to a failure investigator is stress analysis, a test of a part's design. If areas of weakness are present, due to design faults, stress analysis methods can pick up these areas. Common experimental stress analysis techniques available to the laboratory are those of brittle lacquer and strain-gage analysis.

Sprayed on the part to be tested, the lacquer is compounded so it will crack at a known stress when the part is loaded. Analyzing the formation and distribution of cracks in the special lacquer yields a clue as to the validity of design. Strain gages are an even more complicated tool of stress analysis and essentially permit the investigator to measure moving or dynamic loads on a part.

Possibly the best method of showing how these analytical tools can be used to solve a failure mystery is by discussing specific case histories.

Case of the fractured kingpin

One case involved investigating the failure of a kingpin used in a new truck. While driving over an open, smooth road at a speed of from 30 to 40 mph, one of the front wheels collapsed without warning. The truck overturned in a ditch and severely injured the driver. Cause of the accident was centered around the failure of a kingpin, and it became the job of the scientific sleuth to determine whether the kingpin was faulty.

EVIDENCE OF PHYSICAL CONTACT *between a crane and an aluminum high-voltage conductor — legal point in determining responsibility for a fatal accident — was found by spectrographic and metallographic examination of burnt area on the aluminum conductor, and discovered to contain particles of iron and paint from the crane boom.*

Two kingpins were taken from the truck. One was the failed pin; the second was the still-operational pin from the other front wheel.

All parts of both kingpins were tested non-destructively by magnetic-particle inspection. In general, if cracks or defects are found in the part by non-destructive methods, it focuses the investigation to the cause of those defects, simplifying the job. However, no extraneous cracks were found that might indicate the source of cracking.

The next step was to drill small holes at points away from the fracture and in the good kingpin. The drillings were collected and chemical and spectrographic analyses made. Test results showed that the fractured and good kingpin possessed acceptable chemical analysis. No blame could be attributed to poor chemistry of the fractured pin.

A metallographic examination revealed a pronounced difference in structure between the good and bad kingpins, indicating a very brittle condition in the fractured kingpin. Now something concrete had been found which might explain the fracture of one part and not the other.

To verify the results further, hardness tests were made on the good and bad parts. The fractured kingpin showed abnormally high surface hardness. The metallurgist was able to conclude that the kingpin failed because it was abnormally hard and brittle. Cause of the brittleness was traced to improper heat treatment by the manufacturer.

Why did the ladder buckle?

A second case involved a lightweight metal ladder, which had buckled, or apparently buckled, under the weight of a 185-lb man who had been climbing onto a garage roof.

The first object of the investigation was to establish if the ladder was defective in any way. Complete chemical and spectrographic tests showed the ladder to be well within standards specified, and actual physical and destructive tests proved it

to have acceptable strength requirements.

Metallographic tests showed the metal structure to be quite good and without signs of brittleness. There were no signs of prior crackings. All in all, the ladder seemed to meet all known standards and pass all tests. Yet the ladder had buckled in use and the user had been injured.

The next step was to conduct a stress analysis on the ladder to see if the failure was due to faulty design. Extensive tests were conducted on a ladder identical to the one which had buckled. These stresses were measured by brittle-lacquer and strain-gage methods.

The results were surprising. The ladder had withstood an 800-lb static load without failure; it had withstood a test where a 225-lb load was placed on the top rung and the whole ladder pulled over on one leg, so that all the weight was concentrated on one leg; it also had withstood the efforts of a 195-lb man to cause buckling by climbing, jumping, and swaying on the ladder. No signs of unusually high stresses could be found.

A dynamic effect

The investigators were stumped until they realized that a falling, or dynamic, load has a much greater effect on producing failures in metal structures than a static, or gradually applied, load. Tests were designed in which small loads were dropped on various locations on the inclined ladder. It subsequently was shown that a 15-lb weight falling a distance of four feet and striking the ladder in a particular area could cause the exact buckling that had occurred.

The investigators then were able to prove that the injured man had tipped the ladder while climbing from the top rung to the roof, had lost his balance, and fallen on the ladder, causing the buckling.

This fact was sustained when the man later admitted he had hit the ladder. The basic cause of the accident was human; however, laboratory results place emphasis on the low-impact properties of the metal ladder.

Electrocution by high voltage

An unfortunate, yet common, accident that occurs in the construction industry is injury or death by electrocution through contact with high-tension lines. These lines usually are elevated on poles and are contacted by construction equipment such as cranes and loading equipment. The fine legal point involved is whether there has been actual *physical* contact or whether "arcing" has oc-

curred between the high-voltage line and the metal implement.

If direct contact is proved, normally utility companies are free of liability so long as city, state, and national regulations have been followed in the installation.

The case in point involved the determination of whether actual contact had been made between a crane and an aluminium high-voltage conductor. The investigator first photographed the visible areas of burning on the aluminum conductor and crane, then took samples of the paint from the boom and a section of burnt aluminum conductor for spectrographic analysis.

A comparative spectrographic analysis was performed on an area of the aluminum conductor that had *not* been visibly burned. The tests showed that the area where burning had occurred was exceptionally high in iron, whereas the undamaged areas on the aluminum conductor had a low iron content comparable to the normal residual iron content in an electrical conductor alloy.

Additional evidence came from identifying some of the elements of the paint as being present *only* in the burnt areas. Metallic elements are used to color paint and usually are foreign to the aluminum conductor involved. Such elements as titanium, cobalt, chromium, and lead were detected in the burnt sections in high proportions as compared to undamaged sections of the aluminum conductor. Spectrographic analysis of the paint verified the presence of these elements in relatively high proportions.

Examination of the burnt area on the aluminum wire, using a metallograph, showed other interesting results. First it established that the aluminum actually had melted in the burnt areas and the areas weren't created merely by abrasion. Secondly, some iron constituents were found in the burnt area as well as actual paint particles from the crane boom.

Thus it was possible to conclude that the crane boom had made actual physical contact with the aluminum wire. Had arcing been present and no physical contact made, neither the transfer of *high* amounts of iron and particles of paint, nor excessive melting, would have occurred.

Solving the mysteries of metal failures is but one of the fields where scientific fact finding can result in effective action. Knowledge of the methods of approach in metallurgical and other scientific fields can save money and time. ■

RESEARCH AND MONEY

To do research we need money. After all, our dollars keep us anchored to the world of reality. They are necessary to our minds as gravity is to our bodies.

The two activities that have kept the world rolling and given us the daily bread needed for our thinking have been trade and war. We start as children, trading pencils for junk—better than using our fists—and if we were good at marbles, we end up as executives in business and government.

We buy something, or we fight to get something. Why we take the long detour of buying guns to get the things we want instead of buying the same things direct, I don't know. I have been told by politicians that it has been done for thousands of years and so will be done for some more thousands of years. Then why don't we junk our planes and go back to the horse? After all, Caesar conquered the world for Rome with his foot soldiers, and history is only a long record of what the bankers call "past performance."

I should leave these questions to the guardians of the various temples of God and Gold, but I don't. After all, even scienticians need food and shelter, need peace at home and abroad. Business is everybody's business these days. Nearly three hundred years have passed since the Royal Society of England set its rules for scientists.

As Robert Hooke put it, the business of said society was: "To improve the knowledge of natural things, and all useful Arts, Manufactures, Mechanick Practices, Engynes, and Inventions by Experiments (not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rethorick, and Logick)."

"Not meddling with morals and politics"—such I would urge, is the normal condition of tolerance and immunity for scientific pursuits in a civilized state. To quote Mr. Hooke further: "Science should remain aloof and detached, not from a sense of superiority, not from any indifference to the common welfare, but as a condition of complete intellectual honesty."

I wish I could follow Mr. Hooke's advice, but I can't. If I did, I would not feel, to use his term, intellectually honest in our world of today.

— Dr. Piero Modigliani,
Journal of a Scientician

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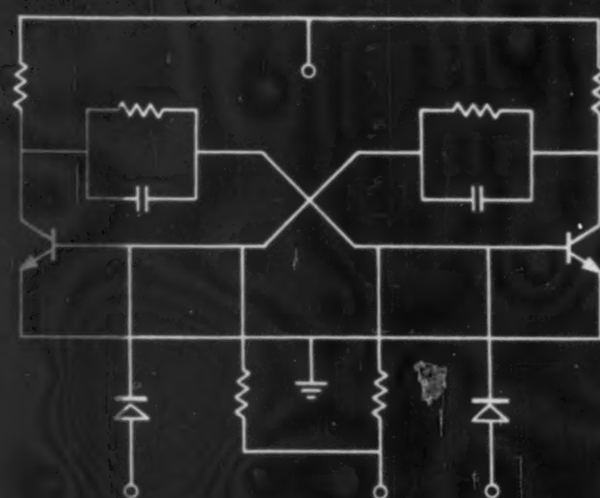

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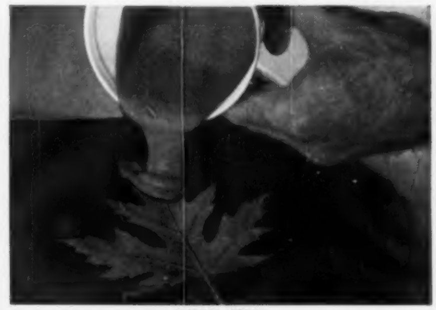

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